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Sewage Research:

Studies on Activated Sludge Bulking. III. Bulking of Sludge Fed with Pure Substances and Supplied with Different Amounts of Oxygen. By R. S. Ingols and H. Heukelekian 849
Oxidation-Reduction Enzymes in Activated Sludge. By R. S. Ingols 862
A New Yardstick for Measuring Sewage Pollution. By W. L. Mallmann 875

Plant Operation:

The Sewage Situation of the City of Los Angeles. By Franklin Thomas. Discussion by Charles Gilman Hyde 879
The Covina, California, Sewage Treatment Plant. By Adolph H. Koebig, Jr. Discussion by R. F. Goudey 895
Operating Experiences in Sewage Treatment at Buffalo, N. Y. By C. R. Velzy, J. W. Johnson and G. E. Symons 907
Symposium on Sludge Filtration and Incineration:
Auburn, New York. By J. T. Lynch and R. E. Millikan 919
Elmira, New York. By G. J. McInerney 929
Town of Greece, Monroe County, New York. By William D. Denise 932
Sewerage in Ancient and Mediaeval Times. By Harold Farnsworth Gray 939

Stream Pollution:

Pollution Control of the California State Division of Fish and Game. By Paul A. Shaw 947
The Allocation of Responsibility for Bacterial Pollution in a Stream. By L. F. Oeming 954

Industrial Wastes:

Studies on the Treatment of Sewage and Textile Wastes by Recirculating Filtration. I. Domestic Sewage and Batch Basis. By Ralph Porges, Henry J. Miles and Herman G. Baity 957

Operators' Reports and Suggestions:

Methods and Problems of Sewer Maintenance. By R. F. Brown 969
Sewer Maintenance. By Fred D. Bowlus 977
The Maintenance of Sanitary Sewers in San Diego, California. By Byrl D. Phelps 982
Discussion. By Carl M. Hoskinson 985
Training Operators of Sewage Treatment Plants. By Clarence MacCallum 987
Report on Presentation of Annual Operator's Award of the New York State Sewage Works Association. By C. C. Agar 992
Willard State Hospital Treatment Plant, Willard, New York. By Reginald A. Murphy 994

Editorial:

The Federation Must Progress. By F. W. Mohlman 999
George B. Gascoigne. By F. W. Mohlman 1000

Proceedings of Local Associations:

Arizona Sewage and Water Works Association 1001
Michigan Sewage Works Association 1005
Pacific Northwest Sewage Works Association 1007
Maryland-Delaware Water and Sewage Association 1008

Reviews and Abstracts:

Discussion of Problems of Sewerage and Sewage Disposal in Metropolitan Boston. By H. P. Eddy, Jr. and A. L. Fales 1011
Pollution of Boston Harbor. By S. A. Greeley 1012
Proceedings of the Twenty-First Texas Water Works and Sewage Short School 1013
Rectangular Tanks—Efficiency and Adaptation to Desludging Mechanism. By H. D. Thatcher 1022
Sewage Disposal at Rochdale 1023
Sewerage and Sewage Disposal in Singapore 1023

References to Sewage Literature 1025

Convention News 1027

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Sewage Research

STUDIES ON ACTIVATED SLUDGE BULKING. III. BULKING OF SLUDGE FED WITH PURE SUBSTANCES AND SUPPLIED WITH DIFFERENT AMOUNTS OF OXYGEN *

By R. S. Ingols and H. Heukelekian

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In the first paper of this series [8] a discussion was presented concerning the factors which cause bulking of activated sludge when it is aerated with air and fed with sugar. Although sugar only rarely appears in domestic sewage and most cases of bulking in sewage treatment plants are not due to sugar, the principles evolved from that work permitted us to predict what conditions were necessary to induce bulking of activated sludge when aerated with sewage in the laboratory. Several experimental conditions which are necessary for the bulking of sludge with sewage were studied and presented in the second paper of this series.[5] The results from these experimental conditions were compared with the conditions under which sugar caused bulking with activated sludge. In each series it was shown that a well oxidized sludge retarded the rate of bulking while a poorly oxidized sludge bulked readily or remained bulky. Whereas the addition of nitrates was ineffective in preventing bulking of sludge with sugar it was quite effective in preventing bulking of sludge with sewage under our particular experimental conditions. The fundamental cause of the similarity of the response with sewage and sugar has been attributed to the relative amounts of the Zooglea and *Sphaerotilus,* or other filamentous organisms, which are present initially. More evidence for the explanation upon the fundamental differences in the action of the nitrates is needed and is presented in this paper.

Calcium butyrate, peptone and sewage do not cause bulking in the laboratory when normal air is used for aeration, but reduction of the oxygen content of the air supply resulted in bulking with sewage. It was considered possible that a similar reduction in the percentage of oxygen in the air supply might produce bulking with other substances that do not respond with normal air. A knowledge of the effect of these substances upon activated sludge in a limited oxygen supply is particularly important because both domestic sewage and many industrial wastes contain substances which are similar to calcium butyrate, such as soaps and fats, and nitrogenous materials which are similar to peptone.

* Jour. Series Paper, N. J. Agri. Exper. Sta., New Brunswick, N. J., Dept. Water and Sewage Research.

Methods

The pure substances were fed in conjunction with a mineral dilution water[8] made with tap water to which had been added:

	Parts per million
Calcium chloride	47
Potassium hydrogen phosphate	40
Sodium bicarbonate	100
Ferric chloride	5
Magnesium sulfate	50

The delivery of a gas mixture consisting of air and nitrogen and containing five per cent oxygen, at a constant rate was made by the use of an apparatus described previously.[5] Nitrates, nitrites, ammonia and organic nitrogen were determined by the usual methods given in "Standard Methods of Water and Sewage Analysis." The sugar was determined as previously described.[8] The volatile acids were determined by filtering off the sludge through coarse filter paper, distilling the acids from the acidified filtrate and titrating the distillate with 0.02 N sodium hydroxide. Because of the high boiling point of the volatile acids, steam distillation was used and four times the volume of the original liquor was obtained for titration. The method was checked and found accurate. Carbon dioxide was determined by the method used previously.[4]

Insofar as possible three doses of food a day were added. The suspended solids were determined in a 200 ml. sample from which the sludge was obtained by centrifuging.[8] The volume of sludge was observed in a one-liter cylinder after settling for one half hour. The sludge index was calculated according to Mohlman.[11] Fresh samples of activated sludge were obtained from nearby plants for each experiment and were used in a fresh condition.

Results

In the first article of this series[8] a comparison was made of the rates of activated sludge bulking when fed sewage to which sugar, calcium butyrate, and peptone had been added and when agitated with an excess of air. A similar experiment has been conducted using five per cent oxygen instead of air and with the mineral dilution water described earlier instead of sewage, and calcium propionate has been added to the above list of foods studied. The results given in Table I show that glucose caused again the most rapid rate of bulking, in fact much more rapid with this supply of oxygen than with air.[7] The next most rapid rate of bulking was caused by propionate, then butyrate and peptone. It should be noted that the sludge accretion was least for the sugar, while Ruchhoft, Kachmar and Moore[12] stated that the large amount of sludge developed from sewage containing sugar would be the cause of difficulty in sewage plant operation. With the fifth dose the highest sludge index did not occur with the highest quantity of suspended solids.

TABLE I.—*Rate of Bulking With Different Food Substances With Five Per Cent Oxygen Gas at 80 Ml./Min./Liter of Sludge Suspension* *

Substances Fed	Quantity			Suspended Solids			Sludge Index		
	Total	As Carbon	As Nitrogen	Initial	2nd Dose	5th Dose	Initial	2nd Dose	5th Dose
	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.			
1. Peptone.....	400	200	71	990	1207	1275	160	158	230
2. Sugar plus.....	500	200	—	990	1132	—	160	788	—
Ammonium Bicarb.....	400	—	71						
3. Calcium Butyrate plus.....	445	200	—	990	1380	1840	160	268	480
Ammonium Bicarb.....	400	—	71						
4. Calcium Propionate plus.....	515	200	—	990	1147	1535	160	254	600
Ammonium Bicarb.....	400	—	71						

* Equivalent to 1 cu. ft. air (20 Per Ct. Oxygen)/6 hours/Gal. of Liquid.

The bulking of activated sludge with the fatty acid salts, calcium propionate and butyrate, at this low oxygen supply, indicates the importance of further studies upon these substances. Peptone caused only a small rise in the sludge index.

It was shown that bulking increased as the amount of sugar fed to a given amount of sludge was increased.[8] The study with a given amount of sludge and increasing amounts of food has been repeated with peptone and calcium butyrate. The results given in Table II indicate that

TABLE II.—*Effect of the Amount of Peptone Fed Upon the Sludge Index When Aerated With 5 Per Cent Oxygen at 80 Ml./Min./Liter of Sludge Suspension* **

Quantity of Peptone	Suspended Solids		Sludge Index		Final Turbidity *
	Initial	Final *	Initial	Final *	
P.p.m.	P.p.m.	P.p.m.			
100	850	1005	175	125	none
200	850	1180	175	135	slight
300	850	1340	175	180	+
400	850	1460	175	212	++
500	850	1430	175	272	+++

* 6 feedings.

** Equivalent to 1 cu. ft. air (20 Per Ct. Oxygen)/6 hours/Gal. of Liquid.

the concentration of peptone affects the bulkiness of the sludge, for as the concentration of peptone was increased not only the quantity of sludge developed was greater but also the relative volume occupied by the larger amounts of sludge increased. A similar picture for calcium butyrate is shown in Table III; increasing the amount of calcium buty-

TABLE III.—*Effect of Feeding Different Amounts of Calcium Butyrate Upon the Bulking of Activated Sludge Aerated with a Five Per Cent Oxygen Gas at 80 Ml./Min./Liter of Sludge Suspension* **

Quantity of Food		Suspended Solids		Sludge Index	
Calcium Butyrate	Ammonium Bicarbonate	Initial	Final *	Initial	Final *
P.p.m.	P.p.m.	P.p.m.	P.p.m.		
200	280	970	1402	145	107
400	280	970	2105	145	143
600	280	970	2640	145	185

* After 5 doses.

** Equivalent to 1 cu. ft. air (20 Per Ct. Oxygen)/6 hours/Gal. of Liquid.

rate fed increased the amount of solids formed and the volume that a unit amount of these solids occupied.

Since it is necessary to reduce the quantity of oxygen used for aeration to obtain bulking of activated sludge fed either peptone or calcium butyrate the question arises as to whether nitrates which are added to the medium can serve as an extra source of oxygen and thus prevent bulking. An experiment was conducted with several food substances in duplicate and 32 p.p.m. nitrate nitrogen was added to one of each pair of sludge food mixture. The results given in Table IV indicate that

TABLE IV.—*Effect of Nitrate Addition Upon Bulking During the Feeding of Sludge with Several Pure Substances and Aerating with 80 Ml. 5 Per Cent Oxygen Gas/Min. per Liter of Sludge Suspension* *

Material Fed	Quantity		Sodium Nitrate N	Doses	Suspended Solids		Sludge Index	
	Carbon	NH_3–N			Initial	Final	Initial	Final
	P.p.m.	P.p.m.	P.p.m.		P.p.m.	P.p.m.		
Sugar and Ammonia.....	200	70	0.0	2	485	870	215	1070
Sugar and Ammonia.....	200	70	32.0	2	485	870	215	970
Glycerin and Ammonia....	200	70	0.0	3	740	1030	215	515
Glycerin and Ammonia....	200	70	32.0	3	740	1105	215	325
Butyrate and Ammonia....	200	70	0.0	3	740	1445	215	290
Butyrate and Ammonia....	200	70	32.0	3	740	1405	215	164
Peptone.....	200	70	0.0	5	740	1275	215	204
Peptone.....	200	70	32.0	5	740	1400	215	121

* Equivalent to 1 cu. ft. air (20 Per Cent Oxygen)/6 hours/Gal. of Liquid.

nitrates are of no value in preventing bulking of activated sludge fed with sugar and of only little value in preventing the bulking of sludge fed glycerin. The addition of nitrates with butyrate brings about a decrease in the sludge index while the absence of nitrates permits an increase in the sludge index with butyrate. When peptone was fed alone to sludge, the sludge index fell slightly, but when nitrates were added with the peptone, there was a much greater decrease in the sludge index. To answer the questions whether the failure of the nitrates to prevent

bulking of sludge fed with sugar indicated lack of nitrate reduction or an insufficient amount of nitrates; or whether there was a reduction of the nitrates in the sludges fed butyrate and peptone, analyses for nitrate and nitrite during the third aeration period with one of the runs are given in Table V.

TABLE V.—*Nitrate and Nitrite Levels During the Third Dose of the Aeration of Activated Sludge in the Presence of Several Substances With and Without Added Nitrates*

Time of Aeration	500 P.p.m. Sugar		445 P.p.m. Butyrate		400 P.p.m. Peptone	
	—	Nitrate Added	—	Nitrate Added	—	Nitrate Added
Hours	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.
			Nitrate Nitrogen *			
Initial	0.0	28	0.75	26	0.0	26
1½	0.5	20	1.0	5.5	0.0	25
3½	1.1	9.5	1.1	0.3	0.2	23
6	0.9	8.0	1.0	0.0	0.3	22
			Nitrite Nitrogen			
Initial	0.1	.7	0.25	1.7	0.1	1.7
1½	0.02	.5	0.12	12.5	0.1	3.0
3½	0.07	.5	0.04	13.7	0.15	4.5
6	0.25	.6	0.02	15.0	0.12	6.0
Total Weight in Mg. of Oxygen Liberated						
6 hr.	—	70	—	58	—	5

* Nitrate nitrogen and not total oxidized nitrogen.

The results indicate that the nitrates added were adequate in quantity as an additional source of oxygen, because in spite of their inability to prevent the bulking of sludge fed with sugar, they were not completely reduced during the six-hour aeration period. There is a small but definite amount of oxidized nitrogen in each of the three experiments to which no nitrates had been added in spite of the fact that oxidized nitrogen was reduced where more was available. This fact has been checked several times by independent experiments but the reasons for the persistence of small amounts of nitrates or nitrites is not clear unless a certain concentration of these ions is necessary for their diffusion to the interior of the sludge floc where they would be reduced. Sugar obtained the largest amount of oxygen from the added nitrate, calcium butyrate only slightly less, while peptone reduced only very little.

These results would seem to indicate that sugar had the highest demand and peptone the lowest but this assumes that the amount of oxygen dissolved was the same. Does the lack of nitrate production and the reduction of the added nitrates indicate an absence of detectable dissolved oxygen with these pure substances during the aeration period? Tests during the first four hours of aeration of the third dose with peptone and butyrate added to the sludge showed no dissolved oxygen in the liquor.

Thus far, the effects of the imposed conditions have been studied only as they have affected the sludge index and in some cases nitrate re-

duction, but there are a number of other measurements of biochemical activities which can yield important information such as: carbon dioxide production, a direct measure of the rate of food utilization, and the production of a specific by-product of metabolism. Smit[13] and Ruchhoft, Kachmar and Placat[12] have analyzed the liquor of activated sludge during the feeding of glucose for volatile organic acids and could fine none. In both of these investigations normal air was used for aeration. It was thought possible that by the use of a limited oxygen supply the presence of volatile acids from the decomposition of glucose could be demonstrated.

TABLE VI.—*A Comparison of the Effect of an Adequate and an Inadequate Oxygen Supply Upon Glucose Metabolism by Activated Sludge During the First and Fourth Doses*

Time of Aeration	80 Ml. Air/Min./L. of Sludge Suspension [1]			80 Ml. 5 Per Ct. Oxygen Gas/Min./L. of Sludge Suspension [2]		
	Carbon Dioxide Produced Expressed as C	Glucose Utilized	Suspended Solids Concentration	Carbon Dioxide Produced Expressed as C	Glucose Utilized	Suspended Solids
Hours	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.
			First Dose			
1	6.4	20	725	6.6	40	725
2	9.5	30		8.0	35	
3	9.1	35		8.9	35	
4	11.5	35		10.1	35	
5	12.3	40		9.8	40	
Total	48.8	160*		43.4	185*	
			Fourth Dose			
1	23.4	200		42.0	480	
2	33.6	200		43.2	20	
3	36.9	100		8.4	—	
4	21.6	—		8.0	—	
5	16.2	—	1420	7.5	—	990
Total	131.7	500*		109.1	500*	

* 500 p.p.m. sugar and 50 p.p.m. urea added for each dose.

[1] Equivalent to 4 cu. ft. of air (20 Per Ct. Oxygen) for 6 hours/Gal. of Liquid.

[2] Equivalent to 1 cu. ft. of air (20 Per Ct. Oxygen) for 6 hours/Gal. of Liquid.

The results shown in Table VI indicate that during the first addition of glucose, the differences in the oxygen supply caused very little difference in the rate of sugar utilization and carbon dioxide production. By the end of the fourth dose the wide divergence in the reactions of the sludge with the ample oxygen supply and the sludge with an insufficient oxygen supply were: (1) a slow steady production of carbon dioxide throughout the aeration period with the ample oxygen supply, while there was a brief high rate production of carbon dioxide with the limited oxygen supply; (2) a slow removal of glucose from solution in the presence of an ample oxygen supply and a very much more rapid removal with a low oxygen supply; (3) a 90 per cent increase in the

suspended solids with ample oxygen and only a 38 per cent increase in the suspended solids with the lower oxygen supply. Analyses for dissolved oxygen during the first and fourth hours of the fourth dose indicated 2.3 p.p.m. dissolved oxygen in the one agitated with air and no dissolved oxygen at either time in the experiment supplied with the limited amount of oxygen. The absence of oxygen continued through the fourth hour in spite of the absence of glucose for two hours and the previous drop in carbon dioxide production.

These results indicated that the glucose was not completely oxidized immediately in the experiment with the limited supply of oxygen and that it was probable that volatile acids were being produced. The experiment was repeated and analyses for volatile acid production during the third dose were included. The difference between the rates of glucose consumption and carbon dioxide production were not as striking as in the previous experiment, but even though these values did not indicate a large anaerobic decomposition of glucose, there was a definite production of volatile acids with the limited oxygen supply, while none could be detected with the ample oxygen supply. No attempts were made to identify the volatile acid, but on the assumption that the volatile acid was lactic acid (a common by-product of the anaerobic decomposition of glucose), 12 mg. of acid (0.085 milliequivalents) accumulated during the period of glucose consumption and then decreased thereafter. A lack of dissolved oxygen in the liquor during the experiment with the limited oxygen supply was indicated by a lack of nitrate production.

The experiment was repeated with calcium propionate, and the results are shown in Table VII. Again the results indicate that the demand for oxygen of both mixtures was low enough during the first dose that there were no real differences in the rates of propionic acid consumption or carbon dioxide and nitrate production with ample and limited oxygen supply. During the fourth dose, however, the rate of propionic acid reduction was much greater in the presence of an adequate supply of oxygen than in the absence of an adequate supply of oxygen. The ratio of quantity of propionic acid consumed to the carbon dioxide produced during the fourth dose with adequate and limited supplies of oxygen, was the same. The limited oxidation of the propionic acid by the inadequate supply of oxygen caused a lower development of sludge under these conditions. The inadequate supply of oxygen is also indicated by the lack of nitrate production. An adequate supply of oxygen during the feeding of calcium propionate produced no change in the sludge index, whereas the sludge index increased more than three times during the feeding of calcium propionate with an inadequate supply of oxygen.

When the experiment was repeated with peptone the results (Table VIII) indicate again that the sludge is not affected appreciably by differences in the quantity of oxygen supplied during the first dose. During the fourth dose, all of the peptone was not used by the activated sludge either with or without an adequate supply of oxygen. The

TABLE VII.—*A Comparison of the Effect of an Adequate and an Inadequate Oxygen Supply Upon the Metabolism of Calcium Propionate by Activated Sludge During the First and Fourth Dose*

Time of Aeration	80 Ml. Air/Min./L. of Sludge Suspension (Equivalent to 4 cu. ft. of air—20 Per Cent Oxygen—for 6 Hr./Gal. of Liquid)				80 Ml. 5 Per Ct. Oxygen Gas/Min./L. of Sludge Suspension (Equivalent to 1 cu. ft. air—20 Per Ct. Oxygen—for 6 Hr./Gal. of Liquid)			
	Propionic Acid Reduced Hourly	Carbon Dioxide Produced Hourly as Carbon	Nitrate Nitrogen Produced Hourly	Sludge Index	Propionic Acid Reduced Hourly	Carbon Dioxide Produced Hourly	Nitrate Nitrogen Produced Hourly	Sludge Index
Hours	P.p.m.	P.p.m.	P.p.m.		P.p.m.	P.p.m.	P.p.m.	
			First Dose					
2	56	16.6	3.4	145	56	15.6	1.2	145
4	24	15.4	3.2		19	11.7	2.0	
5	23	8.5	1.0		35	6.0	0.8	
Totals	103*	40.5	7.6		110*	33.3	4.0	
			Fourth Dose					
2	320	13.5	−3.8		63	9.2	0.0	
4	40	31.4	+3.4		40	9.7	0.0	
5	—	18.1	+5.4	157	34	5.2	0.0	488
Totals	360*	63.0	+5.0		137*	24.1	0.0	
Final suspended solids	1590 p.p.m.				1230 p.p.m.			

* 360 p.p.m. propionic acid was added as calcium propionate and 400 p.p.m. ammonium bicarbonate at each dose.

TABLE VIII.—*A Comparison of the Effect of an Adequate and a Slightly Inadequate Oxygen Supply Upon Peptone Metabolism by Activated Sludge During the First and Fourth Doses of Peptone*

Time of Aeration	80 Ml. Air/Min./L. of Sludge Suspension [1]				80 Ml. 5 Per Ct. Oxygen Gas/Min./L. of Sludge Suspension [2]			
	Organic Nitrogen Reduction	Ammonia Nitrogen Produced	Nitrate Nitrogen Produced	Carbon Dioxide as Carbon	Organic Nitrogen Reduction	Ammonia Nitrogen Produced	Nitrate Nitrogen Produced	Carbon Dioxide as Carbon
Hours	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.
				First Dose				
2	2.0	0	0.8	15.1	10.0	0	0.8	13.4
4	12.0	0	3.2	13.6	5.0	0.2	1.6	12.5
5¼	6.0	0	0.8	7.5	3.0	0.1	0.8	7.4
Totals	20.0*	0	4.8	36.2	18.0*	0.3	3.2	33.3
				Fourth Dose				
2	34.0	8.0	4.0	33.9	12.0	4.0	0.0	15.7
4	25.0	18.0	2.4	31.4	23.0	19.0	0.0	13.4
5¼	8.0	3.0	2.0	16.6	14.0	8.0	0.0	9.4
Totals	57.0*	29.0	8.4	81.9	49.0*	31.0	0.0	38.5
Final suspended solids	1145 p.p.m.				1190 p.p.m.			

* 70 p.p.m. organic nitrogen added at each dose as peptone.

[1] Equivalent to 4 cu. ft. of air (20 Per Ct. Oxygen) for 6 hours/Gal. of Liquid.

[2] Equivalent to 1 cu. ft. of air (20 Per Ct. Oxygen) for 6 hours/Gal. of Liquid.

amount of organic nitrogen used for new protoplasm, as indicated by sludge accretion, was practically the same during the fourth dose with or without an adequate supply of oxygen. That the lower oxygen supply was inadequate on the fourth dose is indicated by the lack of nitrate production and the lower carbon dioxide production. The results on the fourth dose with peptone with low and high oxygen supply were more nearly alike than the results were with either sugar or calcium propionate.

Discussion

The bulking of activated sludge induced when sewage was used furnished valuable information concerning those conditions under which bulking occurs, but it did not indicate what portion of the sewage was most responsible for bringing about the change in the sludge index. It was concluded that the increase in the sludge index was due primarily to the more rapid growth of filamentous organisms, over the Zooglea. The presence of sugar brought a direct response in the growth of *Sphaerotilus* while the lack of adequate oxygen permitted the growth of the filamentous organisms with sewage. With the knowledge of this difference regarding the causes of bulking between sewage and sugar, studies of the effect of three different types of foods with ample and inadequate supplies of oxygen were made. The results have been summarized in Table IX together with other pertinent material and will be used as the basis for the following discussion which will include only the more significant material.

It has been shown [8] that activated sludge bulking can be obtained with sugar in the presence of nitrates and ample oxygen, and now it has been shown that it can be obtained more rapidly when no nitrates are present and the oxygen supply is so limited as to be insufficient to maintain dissolved oxygen, because *Sphaerotilus* grows more rapidly with a limited than an ample supply of oxygen.[7, 14] When sufficient oxygen was used no volatile acids were produced, but when nitrates were not added and an insufficient amount of oxygen was used, volatile acids accumulated, and a smaller amount of growth was obtained, for less energy could be obtained from the sugar molecule under the partially anaerobic conditions. Occasionally, an activated sludge plant receives sewage containing sugar. When this condition occurs, Ruchhoft, Kachmar and Placat [12] claim that operation of the plant will be difficult because of the large amount of sludge which will develop from the sugar. However, most activated sludge plants have a limited supply of oxygen, so that very little sludge could develop from the sugar under these conditions and an increase in the volume occupied by the sludge would occur and this increase in volume would cause the trouble. The bulking of the activated sludge was so much more rapid with sugar when agitated with insufficient oxygen, than with ample, that no attempt was made to study the importance of the carbon-nitrogen ratios or sludge-sugar relation, which were shown to be important with ample oxygen. Interesting as these results with sugar are, they do not ex-

TABLE IX.—*An Outline of the Effect of Pure Substances Upon Activated Sludge Bulking*

	80 Ml. Air/Min./Liter of Sludge Suspension *	80 Ml. 5 Per Ct. Oxygen/Min./Liter of Sludge Suspension **
	Sugar	
(A)	(Ample Oxygen)	(Inadequate Oxygen)
	1. Causes rise in sludge index [8]	1. The low oxygen causes a more rapid rise in the sludge index [7] than air
	2. Rise in sludge index is aided by: [8] *a*) limited nitrogen supply *b*) low sludge sugar ratio	2. Rise in sludge index retarded by added nitrates *a*) nitrates are rapidly reduced
	3. Rise retarded by: [8] *a*) ample nitrogen *b*) high sludge sugar ratio *c*) added nitrates	3. Without nitrates added during aeration period *a*) sugar does not accumulate *b*) volatile acids may be found in liquor
	4. Nitrogen of nitrates is available for protoplasm development [7]	4. Smaller proportion of sugar available for new protoplasm.
	5. Excess ammonia is nitrified [8]	5. Sugar gives a more rapid rise in the sludge index than butyrate or peptone
	6. Large proportion of sugar used for new protoplasm [12]	
B	Butyrate	
	1. 580 p.p.m. causes no rise in sludge index	1. 580 p.p.m. causes a sharp rise in sludge index
	2. Utilized rapidly by sludge	2. Accumulates in the liquor due to lack of oxygen
	3. Excess ammonia is nitrified	3. Added nitrates are reduced
	4. Sludge develops rapidly	4. Sludge develops more slowly
C	Peptone	
	1. 500 p.p.m. peptone permits the sludge index to seek a very low value	1. 500 p.p.m. peptone causes a small, slow rise in the sludge index
	2. Has a higher oxygen demand than sugar [12]	2. Has a lower demand than sugar for nitrate oxygen
	3. Nitrates form readily	3. No nitrification
	4. Slow sludge development	4. Sludge increase not affected by oxygen tension

* Equivalent to 4 cu. ft. of air (20 Per Cent Oxygen) for 6 hours/Gal. of Liquid.
** Equivalent to 1 cu. ft. of air (20 Per Cent Oxygen) for 6 hours/Gal. of Liquid.

plain the cause of bulking with sewage for domestic sewage has been shown to contain no sugar.[13]

The oxidation of the fatty material of sewage by activated sludge in normal plant operation has been shown to be a large portion of the sewage material oxidized.[7] This indicates that an understanding of the reactions of activated sludge toward fatty acids under aerobic and partially anaerobic conditions is very important for a clear insight into the difficulties of sewage plant operation. Our results show that fatty material was readily and rapidly oxidized under aerobic conditions but was oxidized by a limited amount of oxygen only to the extent of the oxygen supplied. When the fatty material is water soluble (such as

propionic or butyric acids) the material remains in the liquid phase, but when the material is insoluble in water, it is probable that it will be adsorbed upon the sludge floc. The water insoluble property of the fatty material in sewage probably explains why so much is removed by the sludge during aeration in sewage treatment plants. When fatty material was fed to activated sludge and it was not oxidized, because of a deficiency of oxygen, the activated sludge showed a sharp rise in the sludge index but the rise was not as large as that with sugar.

A deficiency of oxygen does not mean a total absence of oxygen, but only an amount insufficient to permit complete oxidation of the fatty material within four to six hours. A slight deficiency of oxygen may be frequently found in aeration tanks of a sewage treatment plant, and may explain why some of the fatty material of sewage is not oxidized as indicated by the presence in the yearly averages of 5 and 8 p.p.m. chloroform soluble material in the activated sludge effluent at the Indianapolis sewage treatment plant.[1, 2] This lack of complete oxidation of fatty material may explain why bulking is encountered in plant operation with domestic sewage. That sufficient oxygen prevents bulking with fatty material is shown by the lack of a rise in the sludge index in the presence of nitrates which are less available than oxygen as the hydrogen acceptor.[9]

The need for an ample oxygen supply for sewage treatment by activated sludge was stressed in a previous paper and a better understanding for the necessity of this ample oxygen supply is now available.

The results with peptone, which represents the third type of food studied, show that a high concentration of peptone generally causes a slight but definite rise in the sludge index when the mixture is agitated with a gas containing an insufficient amount of oxygen. It has been shown that the rise in the sludge index with peptone with the same amount of oxygen is less than the rise with equivalent amounts of either sugar or butyrate and it was also shown that the amount of nitrate reduced by peptone was less than the amount reduced by either sugar or butyrate. It may be that the oxygen demand of sludge fed with peptone is higher than the oxygen demand of that sludge fed with sugar [12] when the oxygen supply is ample, but this relationship appears to be reversed when the oxygen supply is limited. When sludge is fed with peptone the amount of sludge developed is not as dependent on the quantity of oxygen as the sludge fed with sugar or butyrate. These results would indicate that the presence of the nitrogenous organic material in sewage neither aids nor hinders greatly the rise of the sludge index during plant operation with an insufficient amount of oxygen.

A study of the organisms responsible for the bulking of activated sludge when it was fed with sugar, indicated that *Sphaerotilus* was the principal causative agent.[8] Heukelekian and Littman [6] showed that the sludge index of Zooglea does not change when it was fed large quantities of sugar which caused natural activated sludge to bulk. When the sludge fed butyrate or peptone with a limited oxygen supply has become

bulky, *Sphaerotilus* is again in evidence but it is not the only filamentous organism and the Zoogleal floc is branched and somewhat filamentous. (Fig. 2 of Butterfield's [3] article.) It is possible that the controlled conditions of a limited oxygen supply in the laboratory can produce a type of pure culture Zooglea floc which will have a higher sludge index than that reported by Heukelekian and Littman.[6] The other filamentous organisms found are *Cladothrix, Dichotoma* (branched type) and *Geotrichoides paludosus* (septate form). Lackey and Wattie [10] state that *Sphaerotilus* causes a sludge to become more bulky than a sludge with other filamentous organisms. This agrees with our results for sugar which induces the growth of *Sphaerotilus* and gives the highest sludge index.

The growth of *Sphaerotilus* in activated sludge fed with sugar is a direct response to the food, but several different organisms respond when the sludge is fed butyrate or peptone with a limited oxygen supply. Why do these organisms grow better than Zooglea? With no detectable dissolved oxygen in the liquor, the distance that small amounts of oxygen can diffuse into a dense Zooglea floc must be very limited. However, filamentous organisms present a large adsorbing surface for the oxygen in transit from the bubbles to the organisms, and are probably like *Sphaerotilus* which grows better in a limited oxygen tension.[7, 14] The change from a dense to a branched type Zoogleal floc may be due to the larger amount of oxygen which can reach all cells of the floc because there is a shorter distance for diffusion of the oxygen.

Conclusions

Bulking of activated sludge occurs when the sludge is agitated with a limited amount of oxygen and fed with sugar, calcium butyrate, peptone, glycerine, or calcium propionate. A concentration of peptone or calcium propionate high enough to show little or no dissolved oxygen is needed to obtain a rise in the sludge index from these food materials. When nitrates are added together with calcium butyrate or peptone no rise in the sludge index occurs. Several filamentous organisms are present in the bulky sludge which is produced by feeding peptone or calcium butyrate. The appearance of the sludges under the microscope and the conditions necessary to produce bulking with calcium butyrate and peptone are more similar to those obtained with sewage than those of sugar and sewage. A deficiency of oxygen is more important in bulking at an activated sludge sewage treatment plant than any particular ingredient of normal domestic sewage.

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OXIDATION-REDUCTION ENZYMES IN ACTIVATED SLUDGE *

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The essential character of the action of enzymes in activated sludge during the purification of sewage is generally recognized by research workers. Those who divide the process into several stages admit that at least one of the stages is dependent upon the organisms present in the sludge floc. In 1926, Harris, Cockburn and Anderson [9] stressed the importance of the enzymes without presenting any specific data to support their claims, although others had previously indicated the necessity of biological action in the sludge for sewage purification. Enzymes which are present in all organisms are "organic catalysts" which initiate reactions and increase the rates of these reactions.

While simple foods, glucose, and amino acids are directly available to organisms, complex derivatives of protoplasm, starch and proteins must be broken down by the hydrolytic enzymes to the simple foods. Some of the simple foods are utilized in the synthesis of new protoplasm by the action of the hydrolytic or similar enzymes in the process of assimilation.

Another and very important group of enzymes brings about the dissimilation of some of the simple food (such as glucose) to carbon dioxide and water to provide the energy necessary for the other functions of the organism. These are the oxidation-reduction enzymes and are of particular importance and interest in the study of the activated sludge process.

When food is fed to a bacterium, growth and then cell division occurs. This increase in the number of cells brings a concurrent increase in the activity of the oxidation-reduction enzymes which increases the rate of growth of each individual cell and the rate of reproduction. After a period of time the food supply is used up and the rate of cell metabolism decreases and the cells are said to be "resting." As the cells approach the "resting" stage there is a decrease in the activity of the oxidation-reduction enzymes, but no marked decline in the number of organisms. Thus, a study of the oxidation-reduction enzymes is not simply a study of the number of organisms in activated sludge. Further all organisms do not use the same paths of dissimilation in breakdown of the same food and so from knowledge of the different organisms present in activated sludge it may be possible to understand why different oxidation-reduction reactions take place.

Perusal of the literature indicates that Wooldridge and Standfast, of the Water Pollution Research Board (British) have published, the only series of articles directly concerned with oxidation reduction en-

*Journal Series Paper, N. J. Agricultural Experiment Station, New Brunswick, N. J., Dept. Water and Sewage Research.

zymes in activated sludge and sewage.[38, 39, 40, 41, 42, 43] They used both the Thunberg technique with methylene blue and the Barcroft respirometer in measuring the activities of sewage, activated sludge and effluent samples primarily for the purpose of finding better and more rapid tests for the strength of sewage and the quality of an effluent; and secondarily for a clearer understanding of the mechanism of the activated sludge process. However, one of the important conclusions at the end of their work is that "the most important factor in biological oxidation of sewage is a series of catalysed oxidation-reduction reactions determined by bacterial enzymes present in either living or dead bacterial cells or liberated by them into the fluid of the reacting system."

On the basis of published results, laboratory experimentation and plant operation an attempt will be made in this paper to indicate the functions of oxidation-reduction enzymes and suggest why certain operation practices produce rapid oxidation of the sewage material.

Methods of Study

Following the publication of the studies of hydrolytic enzymes[11, 12, 17] attention was turned to oxidation-reduction enzymes of activated sludge. A search of the literature revealed that much material had been published that might be reinterpreted to yield information upon oxidation-reduction enzymes. The material involved deals with sludge bulking, plant operation, plant design, causes of differences in behavior of sludges, the relative importance of adsorption and biological assimilation, and the general theory of the mechanism of the activated sludge process. The cardinal points pertaining to the presence or absence or the relative quantities of oxidation-reduction enzymes and utilized as methods for these studies are as follows: (1) The rate of uptake of oxygen or of the decolorization of dyes in the presence of the enzyme and its substrate, (2) the rate of disappearance of some simple material, the substrate, under controlled conditions, (3) the rate of production of carbon dioxide, nitrates or other end products of the reaction, (4) the absence of the reaction in the presence of poisons, (5) the accumulation of certain intermediate products in the presence of an inhibitor to another enzyme in a chain reaction, (6) spectrographic analysis of changes during respiration or activity of the enzyme, (7) the extraction and isolation of the enzyme, (8) the calorific measurement of the heat evolved by the reaction, and (9) specific qualitative tests for the presence of the enzyme.

The first three methods of studying the oxidation-reduction enzymes are used in determining the relative quantities of the enzymes in the materials being tested and do not require an extensive preparation of the sample. The last five methods are used mainly in determining the properties of the enzymes themselves, while the source of the enzyme is of less importance. Each of the first four methods have been used in the studies on the theory of the activated sludge process. For convenience in presenting the material the general work upon the oxygen consumption of sewage and sludge will be discussed after studying the

specific substances which are present in sewage or have been added to activated sludge.

Oxidation-Reduction Enzymes of Inorganic Nitrogen.—Ammonia, which is the reduced form of nitrogen, is an important constituent of sewage, readily measured and studied widely in activated sludge-sewage research. Ammonia is converted to nitrite by the action of a set of enzymes which remove the hydrogen and then add oxygen to the nitrogen. In naturally occurring mixed cultures such as activated sludge, the nitrites are not apt to accumulate in large amounts but are oxidized to nitrates by a separate set of enzymes by the addition of another atom of oxygen to the nitrite. Unlike the dissimilation of some carbonaceous compounds from which carbon dioxide can be produced anaerobically, ammonia can be oxidized to nitrite only with an adequate supply of free oxygen. In an activated sludge aeration tank nitrites accumulate only after a slight excess of oxygen develops in the liquor after the carbon oxidation has receded in intensity. This fact has given rise to the term "nitrification stage." It may be that nitrites are being simultaneously produced and reduced to furnish oxygen for the carbon oxidation during the absence of demonstrable dissolved oxygen, but this could not be demonstrated by chemical experiments and does not seem likely. O'Shaughnessy [22] claimed that this took place in an aeration channel but presented no evidence to support his contention. These enzymes are also unable to compete for the ammonia against the requirements of those organisms using ammonia for the synthesis of new protoplasm as demonstrated by Ingols and Heukelekian [18] and the Water Pollution Research Board (British).[37] The presence of 600 p.p.m. glucose [18] did not affect the activity of these enzymes to any appreciable extent over a period of several days in an excess of ammonia, but nitrates were not formed when there was a slight excess of sugar and no excess ammonia during the six hour aeration period. In fact, when the amount of ammonia nitrogen was just equivalent to that needed for the assimilation of the glucose no nitrates were formed during a six hour aeration period. Had the aeration been continued, destruction of the protoplasm would have taken place with the liberation of ammonia and nitrification would have followed.

Since ammonia remains unaltered in an unseeded aerated sewage for several days, it does not seem to be required for building new protoplasm during this stage and the quantity of the nitrifying enzymes must be very low. The small quantity of the nitrifying enzymes in sewage indicates why the oxidation of sewage is a "two stage process," because time is required for the development of the nitrifying enzymes.

In the development of activated sludge under laboratory conditions with a large excess of oxygen, nitrates are soon formed to almost the entire extent of the ammonia present. In the sewage plants the quantities of nitrates formed vary widely from plant to plant. The liquors of four activated sludges brought into the laboratory in one day varied in their nitrate content from 0.8 p.p.m. to 14 p.p.m. nitrate-nitrogen, while they produced in six hours from 6.4 to 14 p.p.m. nitrate-nitrogen

per gram of sludge.[18] The greater variations of the nitrate content of the sludge liquors at the sewage plant were caused by variations in the conditions which favored nitrate formation as well as in the quantity of the enzymes present.

When the supply of oxygen becomes limited in the aeration tank the nitrates, if present, are reduced and used as a source of oxygen[13, 37] even to the extent of preventing the formation of a bulky sludge under laboratory conditions. In the presence of an excess of oxygen, the nitrate nitrogen is available for the nitrogen assimilation of the activated sludge organisms with a limited supply of ammonia as shown in Table I.

TABLE I.—*Utilization of Nitrate as Nitrogen in the Presence of Oxygen and Lack of Ammonia*

Aeration Time	Glucose		Ammonia		Nitrate	
	Control	Test	Control *	Test	Control	Test
Hrs.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.	P.p.m.
0	450	450	11.0	2.0	2.4	24.0
2	315	310	15.0	1.0	6.0	18.0
4	150	160	3.0	0.5	7.0	14.0
6	0	0	1.0	0.5	8.0	10.0

* From 50 p.p.m. urea.

Oxidation-Reduction Enzymes for Sugars.—Although free sugars are practically non-existent in domestic sewage, they sometimes occur in sewage from trade-wastes in appreciable quantities and have caused trouble at activated sludge plants. Since they are readily and rapidly measured in dilute solutions, they have been studied by several authors.[16, 18, 24] The steps in the enzyme degradation of glucose have been widely studied and there is voluminous literature upon the subject. The first series of steps in the breakdown of glucose occur anaerobically and consist of internal molecular rearrangements of the molecule of sugar without the loss or gain of either hydrogen or oxygen. The second group of reactions requires oxygen or some other hydrogen acceptor and is part of the dissimilation which yields the largest portion of the energy. Some organisms can carry out only the first stage of the degradation while others must complete the second stage to carbon dioxide and water. Some organisms of which *Sphaerotilus* is one, are capable of obtaining their energy under anaerobic conditions by carrying this reaction through the first stage or under aerobic conditions by carrying this reaction through both stages to carbon dioxide and water. Since more energy is obtained from the aerobic phase, growth is more rapid under aerobic conditions. Zooglea is a member of that group which must carry the reaction to completion and therefore some hydrogen acceptors such as oxygen, nitrates, or a dye must be present to obtain its energy. Zooglea may be further differentiated from *Sphaerotilus* by the fact that the Zooglea must have an adequate source of

ammonia nitrogen to build new protoplasm with the glucose that is present.

Sphaerotilus, on the other hand, is able to utilize the glucose that the Zooglea fails to use with a limited supply of ammonia as seen from the rapid increase in the sludge index with an insufficient supply of nitrogen (carbon-nitrogen ratio of 13.3:1) as shown by Ingols and Heukelekian.[18] There are differences in the enzyme activities of the two important organisms found in activated sludge, and sludges will differ in their reaction to glucose depending upon the relative numbers of the two organisms.[18] In a study of bulking with sugar a number of activated sludges were obtained from activated sludge plants and their rate of sugar consumption determined immediately; the rate of sugar consumption of some of them was determined again after several feedings with sugar. These and published results are shown in Table II.

TABLE II.—*A Comparison of Sugar-Consuming Powers of Activated Sludge*

Not Acclimated			Acclimated			
Sludge	Sugar Consumed by 1 gr. Sludge per Hour	Sludge Index	Sludge	Charges	Sugar Consumed by 1 gr. Sludge per Hour	Sludge Index
	P.p.m.				P.p.m.	
70*	8	0	C	3	110	80
74	16	182	76	–	118	—
A**	20	74	B	4	127	56
55	24	0	F	3	150	200
B	30	48	B	7	197	310
64	31		67	–	227	
79	31		65	–	314	
58	32		62	–	350	
C	36	64	Pure Culture Zooglea			
D	56	183	Avg. of 3	–	169	
59	57		*Sphaerotilus*			
72	62		(24)	1	85	
75	63		Limited oxygen supply			
E	65	138	G	3	500	850
F	80	270				
Pure Culture Zooglea						
1	70					
Avg. of 3	102					

* All numbers from article in THIS JOURNAL, 12, 27 (1940).

** All letters from work of this laboratory.

The sludges analyzed immediately show lower rates of consumption than those that have received several doses of sugar. In general the higher rates of sugar consumption during the first dose are correlated with the higher sludge indices. The increases in the rates of sugar consumption with repeated feedings of sugar have been noted by others.[24, 32] These results indicate that the oxidation-reduction enzymes for sugar in sludge are similar in reaction to the hydrolytic enzymes for the complex sugars, such as starch [17, 32] in that both are increased greatly

by contact with the substrate for some period of time. The over-aeration of activated sludge brings about a reduction in both the oxidation-reduction enzymes for sugar [24] and the hydrolyzing enzymes for starch.[17] The degree to which sugar is used by the Zooglea or *Sphaerotilus* will be determined by the quantity of available oxygen and ammonia present. The results in Table III indicate that *Sphaerotilus* grows much more rapidly with less oxygen, confirming Smit's state-

TABLE III.—*Effect of Reduced Quantity of Oxygen Upon the Rate of Growth of Sphaerotilus When Fed Equivalent Amounts of Sugar and Urea*

Per Cent of Oxygen in Gas Used	Suspended Solids		Sludge Volume		Sludge Index	
	Initial	Final *	Initial	Final *	Initial	Final *
	P.p.m.	P.p.m.	P.p.m.	P.p.m.		
20 Per Cent Oxygen.....	355	550	6.5	22.0	183	400
5 Per Cent Oxygen.....	355	565	6.5	80.0	183	1400

* After 3 doses.

ment.[33] Thus, the quantity of enzymes which can convert sugar to energy is dependent upon the previous contact of the sludge with the sugar, while the nature of the utilization will depend upon the organism that is predominant and the amount of free oxygen and ammonia present.

Wooldridge [38] showed that activated sludge was capable of utilizing several sugars as hydrogen donators in the reduction of methylene blue in a Thunberg tube. Activated sludge has dehydrogenase systems that will use formate, lactate, succinate, glucose, fructose and glycerol. On the initial feeding sucrose was not utilized by the sludge indicating a lack of invertase as well as a specific dehydrogenase. Ruchhoft, Kashmar, and Moore [24] state that "When activated sludge was aerated below a pH of about 6.0 the rate of glucose removal was reduced and at pH of 3.9 it was practically stopped. The experiments above pH 7.0 were not conclusive but apparently there was little if any reduction in the glucose rate when the sludge was aerated at values up to 9.6." They further showed that a chlorine dose of 4.0 mg./gr. of sludge caused a 75 per cent reduction in the glucose removal rate. Heating of sludge for 10 minutes at 45° C. injured the glucose enzymes, while 10 minutes at 55° C. destroyed the enzymes. Ingols [15,16] has shown that chloroform, and relatively high concentrations of sodium chloride, prevent the uptake of ammonia or amino acids and thereby block the synthesis of new protoplasm from glucose and ammonia, but that they do not stop completely the breakdown of the sugar for energy.

Oxidation-Reduction Enzymes of Fats.—Fats are another very important constituent of sewage, but no controlled study of their use by activated sludge has come to the attention of the author. This is due partly because their determination is lengthy and relatively inaccurate, especially with small samples. However, the importance of the fats in

TABLE IV.—*An Analysis of the Fat Metabolism in the Indianapolis Sewage Plant from the Basic Figures of Three Annual Reports* [1,2,3]

	Fats in Sewage	Fats Removed from Sewage	Total Solids Removed from Sewage by Activated Sludge		Activated Sludge Wasted		Fats Wasted in Sludge		Fats Oxidized by Aeration	
				Fat / Solids		Wasted / Removal		Fats / Sludge		Fats Oxidized to Fats Removed
	P.p.m.	P.p.m.	P.p.m.	Per Ct.	P.p.m.	Per Ct.	P.p.m.	Per Ct.	P.p.m.	Per Ct.
1936	63.5	58.7	256	23	162	63.7	13.5	8.3	45.2	77.0
1937	58.6	51.1	206	24.8	147	71.4	15.6	10.6	35.5	69.5
1938	61.4	49.2	234	21.2	216	92.4	21.8	10.1	27.4	55.8

the production of energy in the activated sludge process of sewage treatment may be gained from Table IV, which is taken from the annual reports of Indianapolis sewage treatment works.[1, 2, 3] The values shown are in part recalculated from the figures given for the yearly averages of the activated sludge plant. During 1936, 92 per cent of the fat in the settled sewage was removed by the activated sludge and of the fat removed only 23 per cent was discharged with the wasted sludge. Aeration of the sludge brought about a total reduction of 94 p.p.m. solids, while 45.2 p.p.m. of the fats were oxidized. Thus, fat was 48 per cent of the total material oxidized. In 1937, the fats were 60 per cent of the total material oxidized and in 1938 the fats were apparently more than 100 per cent of the total material oxidized. In spite of the obvious error for 1938, the figures show the importance of the oxidation of the fat in sewage purification. Since the fats are such a large percentage of the material oxidized, it is probable that the conclusions to be drawn from the oxygen utilization of sludge sewage mixtures apply here. Since hydrogen acceptors outside of the fat molecules are necessary for all stages in the oxidation of fatty acids, the role of oxygen is of great importance in fat oxidation. This has been verified by experimentation.

Oxidation-Reduction Enzymes of Proteins.—There is some disagreement as to the nature of the structure of protoplasm but all agree that proteins are an essential part of the protoplasm of all organisms. The proteins are composed of many amino acids which must be synthesized or assimilated by heterotrophic bacteria in the presence of other sources of energy. Bacteria will, in the absence of other sources of energy such as glucose, utilize part of the amino acids fed to them for dissimilation and the remainder for building new protoplasm. Many strains of bacteria are capable of utilizing a wide variety of carbon sources for the synthesis of amino acids so that the enzymes for the use of amino acids for energy are readily available to these same organisms. The absolute dependence of all organisms upon the presence of amino acids or their ability to synthesize them, limits the degree of variations in the quantities that can occur with these enzymes. This was demonstrated with the hydrolytic enzymes producing the amino acids.[17] The dependence

of the rate of amino acid utilization by activated sludge upon the presence or absence of another source of energy, glucose, has been demonstrated.[16, 31] Since there is a decrease in the free ammonia-nitrogen during the aeration of sewage with "pure culture activated sludge," [14] it is probable that there is a synthesis of new amino acids and thus little if any oxidation of amino acids during the first 6 hours of aeration. As the aeration period is extended autocatalytic destruction takes place as indicated by the production of some ammonia. Thus, the activity of the enzymes for the dissimilation of amino acids is primarily determined by the presence or absence of other sources of energy, while their quantity is largely dependent upon the total number of organisms.

Oxidation-Reduction Enzymes for Hydrogen Peroxide.—There are a few other oxidation-reduction enzymes that are of general interest, but have not yet been connected with any one type of food. Peroxidase and catalase have been widely studied for a number of years, yet the exact function of hydrogen peroxide in the general scheme of oxidation is not known. Hydrogen peroxide is formed by peroxidase and destroyed by catalase as its concentration exceeds certain limits. Wooldridge [38] has examined several sewages and sludges and has not found either enzyme to be present in definite positive quantities. These tests have been repeated in this laboratory with the same results, so that they are present in not more than traces, if at all.

Oxidation-Reduction Enzymes for Sewage.—The study of oxidation-reduction enzymes in sewage is complicated by the fact that sewage is a mixture of many substances. It is necessary therefore to use the method of the rate of oxygen consumption or carbon dioxide production to get an estimation of the active oxidation-reduction enzymes in the sewage sludge mixture. The measurement of oxygen consumption by sewage-sludge mixtures has been widely studied for both theoretical considerations and plant control. The results of various authors are in good agreement in regard to the rate of oxygen consumption of mixtures of sewage and activated sludge. In general there is a high initial rate which falls to a low level with time.[4, 6, 7, 8, 10, 19, 20, 26, 27, 28, 29, 30, 41] The duration of the high initial level is controlled largely by the strength of the sewage and the type of the sludge. The height of the initial peak is controlled by the oxygen available, the temperature of the mixture, the concentration and nature of the sludge and to a lesser extent by the sewage strength. A high sludge concentration with its high enzyme concentration induces a high rate of oxygen consumption and shortens the period of high rate consumption. With a nitrifying sludge the quantity of carbonaceous material and ammonia in the sewage determines the duration of the high rate of oxygen consumption [26, 27]; with a non-nitrifying sludge the quantity of readily available carbonaceous material determines the duration of the high rate. It was pointed out earlier that a lack of either free ammonia or free oxygen prevents the formation of nitrites. The prolonged prevalence of these conditions has been shown to produce a non-nitrifying sludge.[27]

When the oxygen uptake of sewage alone is compared with the rate

of oxygen uptake of the sewage plus sludge in an unlimited supply of oxygen, the rate of uptake of the mixture may be as high as sixty to one hundred and twenty times that of the sewage alone. Even if the quantity and quality of the food in the sewage is the limiting factor in the rate of oxygen uptake of the sewage-sludge mixture, the results indicate that the oxidation-reduction enzyme concentration of the sludge is many times that of the sewage alone.

Theriault [35] has modified slightly the unimolecular equation developed by Phelps [23] and has shown that it fits well the data for the biochemical oxidation of sewage organic matter in polluted streams. This expression is frequently given as:

$$y = L(1-10^{-Kt})$$

where y = the B.O.D. satisfied in time t
L = the initial total carbonaceous B.O.D.
K = a velocity constant of 0.1 at 20° C.
and t = time in days

Theriault and McNamee [36] later show that this equation is not adequate to predict the rates of oxygen consumption by mixtures of activated sludge and sewage and that a second expression should be included in the above equation with a velocity constant about twenty times greater than that of the sewage oxidation rate. The expression is given as:

$$y = L_1(1-10^{-K_1t}) + L_2(1-10^{-K_2t})$$

where y = the B.O.D. satisfied in time, t
L_1 = the first stage B.O.D.
L_2 = the immediate high rate B.O.D.
K_1 = the velocity constant of 0.1
K_2 = the high rate velocity constant of approximately 2.0

Moore [21] believes that the data of Kessler and Nichols [19] might be more adequately explained with a third factor in the equation with a velocity constant of 15–20. This higher value for the velocity constant would seem to more nearly fit the very high rate of oxidation in a sludge-sewage mixture, but it is not within the scope of this paper to discuss which equation best suits the data but to point out the high rates of oxidation obtained by the oxidation-reduction enzymes present in activated sludge. Since it is known from the laws of enzyme activity that rates of an enzyme reaction are directly proportional to the enzyme concentration, the oxidation-reduction enzyme concentration of an activated sludge-sewage mixture must be sixty to one hundred and twenty times that of sewage alone. The rate of oxygen uptake by activated sludge-sewage mixtures varies considerably from one sludge to another and even with the sludge from one plant from time to time. The causes of these variations have been studied by several workers.

Ruchhoft and Smith [25] showed that the ability of a sludge to oxidize a mixture of glucose and peptone is increased by a previous high load of sewage, and is decreased by overaeration.[4, 24] This has been shown

by Bloodgood [4] to be true within the limits of sewage plant operation at Indianapolis and by Spiegel, Kappe and Smith to be true for several smaller plants.[34] Bottcher [5] showed that reaeration of activated sludge at Berlin decreased the activity of the sludge and would not be used in a new plant. These results indicate that the sludge organisms are quite sensitive in their ability to produce oxidation-reduction enzymes to cope with an increased amount of sewage or other food, but that they are unable to maintain this heightened activity without a constant and adequate supply of food. This indicates that the organisms are made more active by the food but that they become less active during the resting stage and that some time is required to enter the active stage again. This immediate decrease with overaeration is quite different from the increase in most of the hydrolytic enzymes during the first 4 days of prolonged aeration of the sludge.[17] The decrease in the oxidation-reduction enzymes is an attempt of the organism to conserve its own protoplasm, whereas hydrolytic enzymes are necessary for the utilization of any new food source. Wooldridge and Standfast [42] have shown that an extreme overloading (3 to 4 times normal) may depress the oxygen consumption greatly, probably because of the changes in the floc surfaces which prevent the diffusion of oxygen.

By using the Thunberg technique with methylene blue, Wooldridge [38] showed that sludge plus sewage reduced the methylene blue in 30 per cent less time than sludge plus boiled sewage in which all enzymes had been destroyed. This would indicate that the sludge had twice the concentration of oxidation-reduction enzymes as the sewage. This low value may be due to the fact that the oxidation-reduction potential of methylene blue is lower than that of oxygen. Using this same technique Wooldridge showed that nitrate was a good hydrogen acceptor. By means of the Barcroft respirometer Wooldridge and Standfast [42] showed that increasing the temperature from 18° to 37° C. brought about a large rise in the rate of the enzyme activities. These effects of temperature have been repeated by Sawyer and Nichols [28] and Sawyer and Roblich.[30] The pH range of oxygen consumption for sludge-sewage mixtures [42] is essentially the same as those values given earlier for glucose.[24] Wooldridge and Standfast showed that from pH 6.0 to 9.0 the rate of oxygen consumption was only slightly changed but that a possible optimum existed at pH 7.3. In another article [40] these authors proved that the oxidation of sewage with activated sludge yielded no combustible gases and no nitrogen from an aerobic decomposition of the sludge. These same authors [39, 43] have shown that the organisms can be poisoned so that growth is stopped, yet the oxidation-reduction processes can proceed at a greatly reduced rate. This was partially confirmed, with glucose by this laboratory.[15, 16]

Heukelekian and Ingols [19] have studied the production of carbon dioxide by mixtures of activated sludge plus sewage. Their findings are in excellent agreement with the results obtained with oxygen consumption studies upon activated sludge and sewage and references to their work have been included in this section.

Specific Conclusions

From the material presented in this paper, the following conclusions concerning oxidation-reduction enzymes of activated sludge may be drawn:

(1) Nitrifying enzymes are active only in an excess of both free ammonia and oxygen.

(2) Sewages contain very little nitrifying enzymes; sludges contain varying quantities of these enzymes, depending upon the food and maintenance of free oxygen.

(3) The dissimilating enzymes for glucose are increased by feeding the sludge glucose; the nature of the activity of the enzymes formed is determined by the relative amount of nitrogen added with the sugar and the relation of the sludge to the sugar.

(4) Fats may form over 50 per cent of the material used for energy by activated sludge when aerated with sewage.

(5) Very little dissimilation of the proteinaceous materials in sewage takes place during the usual aeration period with activated sludge.

(6) Peroxidase and catalase are present in sewage or sludge only in very slight traces.

(7) The oxidation-reduction enzyme concentration of sludge sewage mixture may be sixty to one hundred and twenty times that of a sewage alone.

(8) The oxidation-reduction enzyme system is increased by a high sewage load and decreases with overaeration.

(9) Increasing the temperature increases the activity of the oxidation-reduction enzymes between 10° and 37° C., while 45° C. for ten minutes greatly retards their activity, and 55° C. for ten minutes destroys it.

(10) The enzymes are readily active over a range from pH 6.0 to 9.0.

(11) Some poisons are capable of blocking assimilation without destroying the dissimilation activity.

General Conclusion

From this specific material, the following general conclusions can be drawn:

1. Oxidation-reduction enzymes are essential in activated sludge production and in the purification of sewage by this process.

2. There is a direct relation between the concentration and the rate of activity of enzymes so that the activity of activated sludge is dependent upon the concentration of the oxidation-reduction enzymes.

3. The rate of activity of the oxidation-reduction enzymes is affected by the temperature, the amount of oxygen supplied, pH of the medium and the type of food.

4. The type of activity of activated sludge is determined by the groups of oxidation-reduction enzymes developed.

5. The groups of oxidation-reduction enzymes which develop are de-

termined by the types of food, the amount of oxygen supplied, and the temperature.

6. The concentration of the oxidation-reduction enzymes for a particular food is dependent upon the nature of the food and the previous contact of the sludge with that food.

7. The concentration of oxidation-reduction enzymes is greater in activated sludge than in sewage.

Considerable information on oxidation-reduction enzymes is available or can be deduced from indirect evidence, but many questions remain unanswered. From a practical as well as theoretical standpoint one of the most interesting questions is "Why do some organisms grow more readily as the oxygen concentrations decrease, while others function better at higher oxygen concentrations?" The answers to this and similar questions are of fundamental importance and are necessary for understanding the complete mechanism of activated sludge, and hence for improvement and intensification of the process.

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A NEW YARDSTICK FOR MEASURING SEWAGE POLLUTION *

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Through the processes of survival and adaptation each species of plant and animal has perfected mechanisms and habits whereby the species can perpetuate itself. Parasites of man and animal are no exception. Many of the intestinal parasites of man and animal perpetuate themselves by the establishment of their kind in the intestinal tracts of new hosts by the simple means of passing from the intestinal tract of a host in the fecal discharges and then waiting for the accidental but inevitable contamination of the food by the new host.

The transmission of intestinal parasites by sewage probably had its beginning long before man ascended to his present position in the animal kingdom. The waste materials from the intestinal system of all animals as well as men are health hazards to their kind or for other animals which happen to be hosts for the same parasites. In general, the intestinal discharges of men are the most dangerous wastes but in some instances those of other animals may also carry disease germs communicable to man.

Man apparently learned early in history that the contamination of his food and drink by fecal discharges frequently resulted in violent illness and sometimes death. Widespread epidemics of early man were prevented not by preventive measures but by the fact that communities were small and water courses were not contaminated. Widespread epidemics of intestinal diseases appeared with the advent of the industrial age and the urbanization of the population. Unfortunately, even today with all our knowledge of disease transmission and means of control, water supplies still sometimes carry dangerous sewage contamination. Water borne epidemics still occur.

During the past seventeen years in the United States and Canada, with a combined population of 138,000,000 people there were five hundred epidemics, 125,000 persons ill, and 1,200 dead as the result of sewage contaminated water. At Salem, Ohio, in 1920; at Cochrane, Ontario, in 1923; and at Chamberlain, South Dakota, in 1933, the proportion of the population affected by water borne disease was so great that Red Cross nurses were needed to handle the cases.

The health hazard of sewage and the diseases carried can be vividly depicted by epidemics of water borne disease due to sewage contaminated water. The following epidemics of recent years show the disease germs carried in sewage.

Many epidemics of typhoid fever have been traced to contaminated

* Presented at the Meeting of the Michigan Sewage Works Conference, Lansing, May 10, 1940.

water supplies. Perhaps one of the most spectacular epidemics of recent years occurred in 1925 at a Chautauqua camp meeting at Winona Lake, Indiana, when a thousand persons contracted typhoid fever.

Although it has been known for many years that amebic dysentery was transmissible through sewage contamination, the first epidemic of this disease occurred at Chicago at the time of the last World's Fair. This epidemic was traced to sewage contaminated waters. Over fourteen hundred cases of amebic dysentery occurred. One hundred of those affected, died. Since then two similar epidemics have occurred.

Bacillary dysentery has frequently been spread by sewage contaminated water supply. The most recent outstanding epidemic of this disease occurred at St. Jerome de Matane, Quebec, in 1935. Two thousand people were ill and forty died.

Widespread epidemics of milk diarrhea are frequently caused by sewage contaminated water. Most of these epidemics are not recorded in literature. In many of these epidemics practically every one of the persons using the affected water contracted this disease.

All of these epidemics and many others recorded in the literature were due to the contamination of the water supply by raw sewage. All of these epidemics dramatically portray the fact that raw sewage is potentially at all times a factor of intestinal borne diseases and must at all times be treated as a health hazard.

The sewage disposal plant has been developed not as a means of eliminating a public health hazard, but as a means of avoiding a nuisance and the restoring of our water ways to their original condition whereby fish life would again be possible. The health hazard has been largely ignored because the public has accepted the fact that streams are largely "open sewers" and have long forgotten the recreational possibilities of these waterways.

Now that many of our rivers in Michigan have ceased to be "open sewers" by the introduction of sewage disposal plants the streams may be used for recreational purposes provided the disposal plant has eliminated the health hazard from the sewage effluents.

During the process of sewage treatment irrespective of the method the disease producing bacteria are held under adverse conditions and many of them undoubtedly succumb. In no part of the sewage disposal system are conditions conducive to their development or even survival.

At each step in the biological method of sewage disposal different types of bacteria supplant the incoming bacteria, thus the disease producer is crowded out by the multiplication of other organisms and is injured by contact with the by-products of the new microflora.

It is impractical to test sewage and sewage effluents for the presence of disease producing bacteria. So the number of coliform organisms has been used to measure the degree of pollution. If the coliform organisms did not multiply during the process of treatment the diminution in their numbers might serve as a rough index of the removal of disease producers.

Under certain conditions coliform organisms do multiply in water.

The writer (1), in a study of the behavior of coliform organisms in a swimming pool, demonstrated that the number increased during periods when the pool was not used. Mallmann and Sypien (2) also showed that coliform organisms in a small inland lake actually increased in number. If coliform organisms will increase in number in a swimming pool or in small inland lakes, it seems reasonable that they would readily multiply in sewage and sewage effluents.

Assuming that coliform organisms reproduce in sewage treatment plants their presence in the effluent would have little bearing as a measurement of the removal of pathogens, except that the absence of the coliform group would be an excellent index of the absence of pathogenic bacteria. Inasmuch as the effluent of most biologic treatment processes contains large numbers of coliform organisms, these organisms are apparently poor indices of health hazard and thus have little value for measuring the efficiency of the various biological processes of sewage purification in the removal of pathogens.

In 1928 the writer (1) demonstrated that streptococci were better indicators for swimming pool water quality because they represented mouth contamination and because they did not reproduce in the swimming pool waters. Mallmann and Sypien (2) in a study of bathing beaches demonstrated that streptococci apparently did not multiply in lake water.

TABLE I.—*Reduction of Colon and Streptococci Indices During Passage Through a Sewage Disposal Plant*

Date	City	Raw		Primary Effluent		Rock Filter		Final Effluent	
		Colon	Strept.	Colon	Strept.	Colon	Strept.	Colon	Strept.
1/16/40.....	Lansing	1,000,000	1,000	1,000,000	1,000			100,000	100
2/ 7/40.....	Battle Creek	1,000,000	1,000,000					1,000,000	10,000
1/22/40.....	Muskegon	100,000	10,000					10,000	10,000
1/26/40.....	Muskegon	100,000	10,000					100,000	1,000
2/ 6/40.....	Muskegon	1,000,000	100,000					1,000,000	10,000
1/22/40.....	Grand Rapids	1,000,000	10,000					100,000	1,000
1/31/40.....	Holland	1,000,000	100,000					1,000,000	10,000
2/ 6/40.....	Flint	100,000	10,000	1,000,000	10,000	Not checked	Not checked	10,000	100
1/22/40.....	Muskegon Hgts.	10,000	1,000	10,000	1,000	100	10	100	10
5/ 1/40.....	Muskegon Hgts.	1,000,000	10,000			100	100	100	10

Recently Mallmann, Botwright and Churchill (3) found that slow oxidizing agents prevent the growth of gram-negative organisms and allow the unhampered growth of gram-positive bacteria. A broth medium made according to the formula of Darby and Mallmann (4) containing 1 to 5,000 of sodium azide has been found to grow streptococci and inhibits the coliform groups. Using this medium sewage samples have been examined for the presence of streptococci. This medium makes possible an easy procedure applicable to routine laboratory practice.

During the past winter samples of sewage have been examined from various plants to measure the removal of streptococci by the various biologic procedures of purification. Composite samples were collected in all instances. The results are presented in Table I.

These data show that in winter there was only a slight reduction of streptococci during the passage of the sewage through the sedimentation tank. The reduction in the secondary treatment where aeration has been used, as at Lansing and Jackson, was slight. Data are not presented.

When the sewage effluent was passed through sprinkling filters (Flint) and through contact beds (Muskegon Heights) a very marked reduction in streptococci occurred.

These data show that, although primary treatment may reduce materially the oxygen demand of the sewage, it does not have much effect upon the reduction of pathogens as measured by the reduction of streptococci.

The data presented represent winter conditions only. Further studies are in progress. These studies are presented primarily to acquaint others with these new technics, and in order that others may also contribute to this work.

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Plant Operation

THE SEWAGE SITUATION OF THE CITY OF LOS ANGELES *

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Historical

Scarcity of water was probably a major factor in the circumstances which caused the City of Los Angeles to adopt a crude form of sewage disposal by using the flow for irrigation instead of emptying it into the bed of the river. An extended period of drouth was about to be ended by the wettest winter of record, 1883–84, bringing 38 inches of rain; when in 1883, the authorities of the city of about 15,000 people made a contract with the South Side Irrigation Company for the sale of the sewage of the San Pedro Street sewer. The flow amounted to 3.58 cu. ft. per second and with later increases, a supplementary contract of 1895 (when the population had reached 70,000) agreed to deliver 6 cu. ft. per second or more until 1903. The prevailing price was at the rate of $2 per acre foot. The company irrigated about 2200 acres.

Objections of the health authorities to the use of sewage for irrigation of vegetable farms, and the growth of the city in the direction of this land, resulted in the abandonment of the practice with the completion of the central outfall to the west in 1907, at which time the city had a population somewhat over 200,000.

Los Angeles' first outfall extended 10 miles to Hyperion and was constructed of brick with diameters of 4.5 ft. to 6 ft. and had a capacity of 90 cu. ft. per second. At the ocean the line connected with a 52 in. redwood pipe carried out 2000 ft. upon the Hyperion pier to a submerged end. After about 20 years of service, the central outfall had been subject to so much disintegration that its use was discontinued except for the minor flows from El Segundo and the municipal airport.

The exceptional post-war development which took place in Los Angeles had taxed, even by 1920, the capacity of the central outfall sewer, while the nuisance and menace created by the discharge of that volume of unscreened sewage near the shore had aroused justifiable complaints and official threats. Early in 1921, a "Special Sewage Disposal Commission," composed of George W. Fuller, George C. Whipple, and William Mulholland, investigated the situation and submitted a report, the findings and conclusions of which, as confirmed by subsequent events and developments, still constitute a sound general pattern to be followed in a comprehensive program of sewage disposal for Los

* Presented at the Spring Meeting of the California Sewage Works Association, Avalon, California, May 20, 1940.

Angeles. Facilities which have been provided fall far short of those recommended by this Commission, but nothing which has been done is in serious conflict with its recommendations.

The Commission, in April, 1921, recommended in part: That a new ocean outfall be constructed of a capacity at least 325 cu. ft. per second; that a plant for fine screening of sewage be installed; that the screened sewage be dispersed at Hyperion by means of deep multiple outlets; that an activated sludge plant of at least 2,500,000 gal. daily be built to explore the suitability of the process for this system, with provision for adding other units when desired. It was anticipated that one of two suggested locations would be used: (*a*) near the Baldwin Hills with the effluent being used for irrigation or being discharged into Ballona Creek; or, (*b*) near the Los Angeles River in the southeastern industrial district.

At a sewer bond election in June, 1921, when a proposition for $12,250,000 was submitted, the voters expressed overwhelming disapproval. The defeat was due principally to objection by civic bodies and newspapers to discharging increasing quantities of raw sewage adjacent to populous beach areas and to the contentions of conservation advocates that the constituents of the sewage should be put to economic use.

In August, 1921, subsequent to and in view of the defeat of the bond proposal, the Special Sewage Disposal Commission submitted a supplementary report involving a reduced project estimated to cost $4,000,000 and which omitted the controversial new outfall sewer to Hyperion. However, before official action was taken concerning another election, the very heavy and continued rains of December, 1921, caused such overloading of the sewers in the southerly part of the city that manhole covers were floated and sewage ran in the streets. A break occurred in the central outfall operating under pressure and escaping sewage flowed into Ballona Creek.

These alarming conditions awakened public responsibility and aroused civic leadership to a point where temporary makeshifts were abandoned. By common consent a project was formulated providing: for a screening plant on the central outfall; for the much malignant north outfall with intercepting branches to relieve overloaded trunk sewers; for a screening plant on the new outfall; and for a submarine discharge line extending 5000 feet into the ocean. In August, 1922, a bond proposition for $12,000,000 was approved by a four to one vote. The new facilities were rushed to completion and went into service in 1924 and early 1925. For approximately nine years the screenings were ejected to the top of the sand dunes adjacent to the beach at Hyperion, but in 1934, an incinerator for these screenings was placed in operation and the dewatered solids were burned. In 1937, operation of the incinerator ceased when an arrangement was made for the screenings to be hauled away without cost to the city. Shortly after the completion of the north outfall, use of the old central outfall was largely abandoned due to its physical deterioration. Except for a detached

treatment plant at Los Angeles Harbor and some new relief sewers, the city's system has been little modified since 1925.

Geographical and Topographical Features

While the pattern of trunk sewer locations in most cities resembles a fan, in Los Angeles it resembles a letter "U" because of the Santa Monica Mountain Range which separates San Fernando Valley from

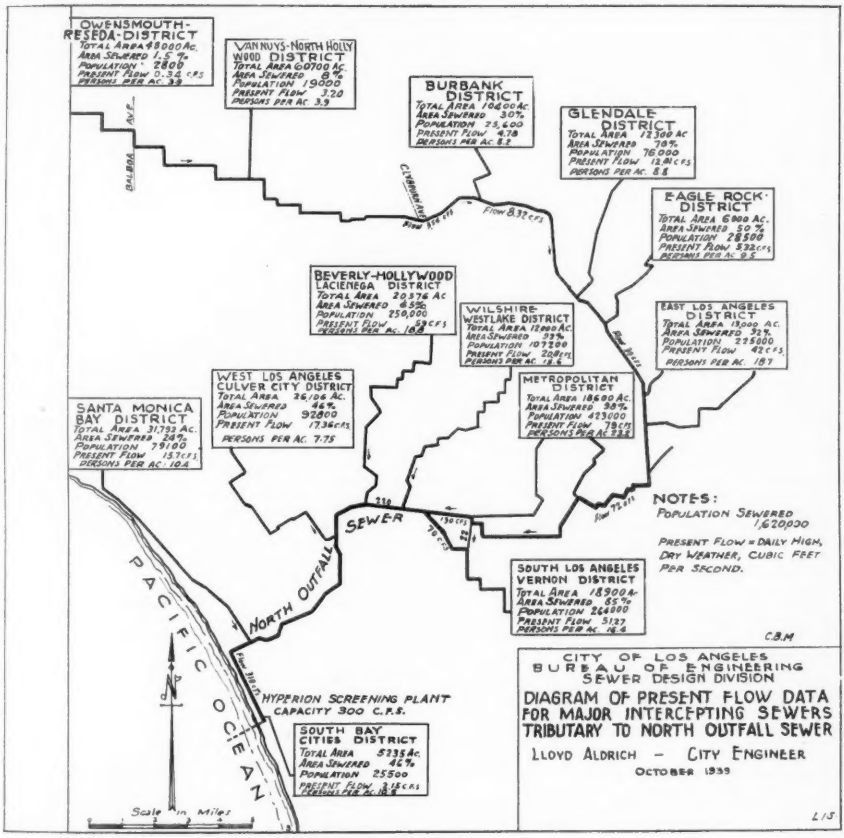
OWENSMOUTH-RESEDA DISTRICT
VAN NUYS-NORTH HOLLYWOOD DISTRICT
BURBANK DISTRICT
GLENDALE DISTRICT
EAGLE ROCK DISTRICT
BEVERLY-HOLLYWOOD LACIENEGA DISTRICT
WILSHIRE-WESTLAKE DISTRICT
EAST LOS ANGELES DISTRICT
WEST LOS ANGELES CULVER CITY DISTRICT
METROPOLITAN DISTRICT
SANTA MONICA BAY DISTRICT
SOUTH LOS ANGELES VERNON DISTRICT
SOUTH BAY CITIES DISTRICT
NORTH OUTFALL SEWER
HYPERION SCREENING PLANT CAPACITY 300 C.F.S.
PACIFIC OCEAN
NOTES:
POPULATION SEWERED 1,620,000
PRESENT FLOW = DAILY HIGH, DRY WEATHER, CUBIC FEET PER SECOND.
CITY OF LOS ANGELES
BUREAU OF ENGINEERING
SEWER DESIGN DIVISION
DIAGRAM OF PRESENT FLOW DATA FOR MAJOR INTERCEPTING SEWERS TRIBUTARY TO NORTH OUTFALL SEWER
LLOYD ALDRICH – CITY ENGINEER
OCTOBER 1939
Scale in Miles

Fig. 1.

the Coastal Plain. The distance by airline from the head of the north outfall in the Canoga Park region to Hyperion is 21 miles, but the distance along the natural drainage of the Valley around the east end of the Santa Monica Mountains, thence to the west coast is 55 miles. This line then is affected by the complications and difficulties which might be expected to beset the longest closed sewer in the world (Fig. 1).

The elevation of the upper end of the north outfall 55 miles from Hyperion is 775, while 23.5 miles downstream where the line makes the bend around Griffith Park the elevation is 440. At the Enterprise

Street Crossing of the Los Angeles River as the line turns toward the west coast 22 miles away, the elevation is 225.

Table I shows that the sewage from the most remote areas of the Los Angeles system, although small in amount, requires over 18 hours

TABLE I.—*North Outfall Sewer. Distribution of Area, Population; Capacity and Dry Weather Daily High Flow, 1939*

Distance from Hyperion		Tributary District Junctions	Area		Persons per Acre	Population		Flow C.F.S.*		Capacity C.F.S.
Miles	Hrs.		District	Per Cent Sewered		District	Accumulated	District	Accumulated	
53.5	18½	Canoga Park	48,000	1.5	0.06	2,800		0.34		
42	13½	Van Nuys—North Hollywood	60,700	8	0.31	19,000	21,800	3.20	3.54	51
33.5	10	Burbank	10,400	30	2.5	25,600	47,400	8.2	11.74	60
30	8½	Glendale	12,300	70	6.17	76,000	123,400	12.81	24.55	
27	7½	Eagle Rock	6,000	50	6.75	28,500	151,900	5.32	29.87	72
25	7	East Los Angeles	13,000	92	17.3	225,000	376,900	42	71.87	121
19	5	Metropolitan	18,600	98	23.2	423,000	799,900	79	150.87	185
11	3½	South Los Angeles—Vernon	18,900	85	14.0	264,000	1,063,900	51.27	202.14	
10.5	3½	Wilshire—West Lake	12,000	92	8.94	107,200	1,171,100	20.8	222.94	340
9.75	3	Beverly—Hollywood	20,576	65	13.02	268,000	1,439,100	53	275.94	
8.75	2	West Los Angeles	26,106	46	3.54	92,800	1,541,900	17.36	293.30	450
3	1	Santa Monica Bay	31,792	24	2.49	79,100	1,621,000	15.7	309.00	
—	—	Hyperion					1,621,000		309.00	450

* Due to the fact that the daily high flows from different districts do not coincide in the outfall, the actual dry weather peak at Hyperion is 275 c.f.s.

to reach Hyperion. The flow approximating 20 c.f.s. as a daily peak, from the Glendale junction has an 8½ hour journey to the ocean, while 150 c.f.s., or half of the flow at Hyperion, travels from the junction of the tributary serving the business district for 5 hours in the north outfall (Fig. 2). Expressed in the reverse order, 95 per cent of the flow is 3 hours or more old; 75 per cent is more than 3½ hours old; 50 per cent is 5 hours old; and 20 per cent has been in the north outfall 7 hours when it reaches Hyperion.

METROPOLITAN ASPECTS

The authorities of the City of Los Angeles at various times in the past have exemplified the "Good Neighbor Policy" toward a number of the adjacent smaller communities, in respect to assuming the responsibilities of sewage disposal. In a number of instances the generosity represented by the terms of the agreements with these communities is of a scope showing little regard for the interests of Los Angeles. Examples of some of the arrangements are: One city of 70,000 persons acquired a perpetual right to discharge, through 25 miles or more of outfall sewer, all of its sewage with no limitations on quantity, in return

for the construction of a few miles of the outfall which also serves as the carrier for sewage from some of the more remote portions of Los Angeles. Some cities make annual payments for operation and maintenance expenses on a basis of measured flow but no provision is made

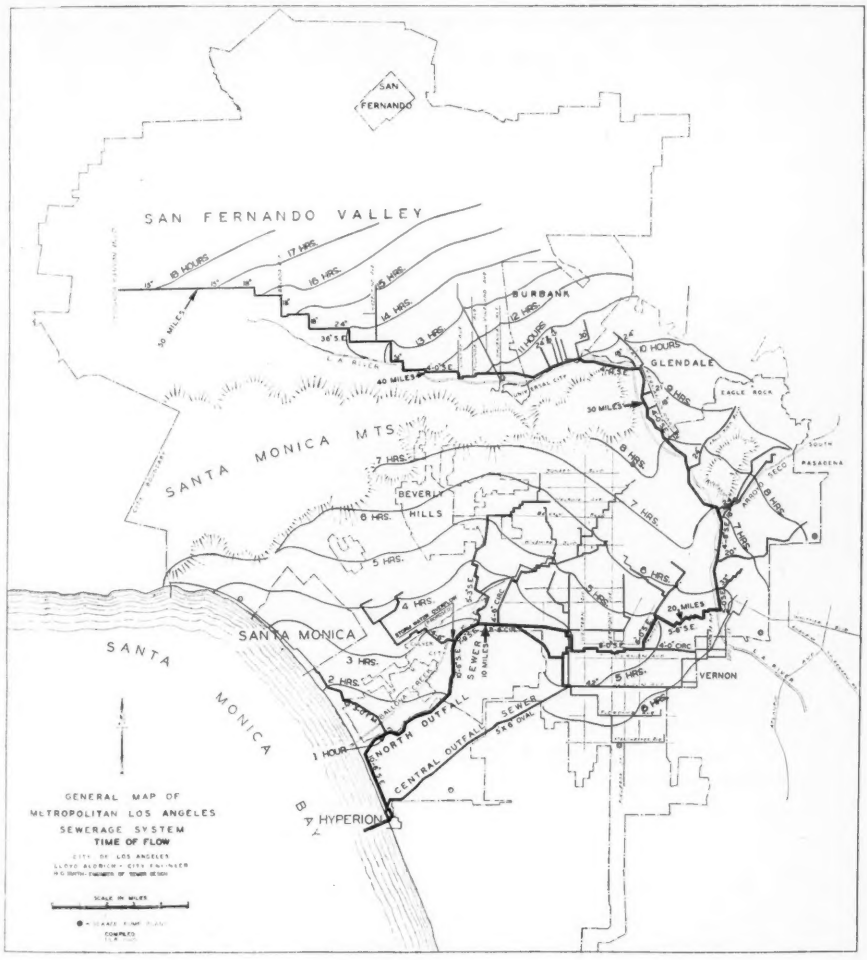

FIG. 2.

for payments toward past or future construction costs. Another city, having a population of 8,000, by payment of $57,000 toward acquisition of right-of-way, obtained a perpetual right to the discharge of an unlimited flow. Fourteen of these adjacent areas at this time contribute the sewage of 290,000 persons to the Hyperion screening plant. This number is more than 22 per cent of the estimated 1,300,000 population within the City of Los Angeles tributary to Hyperion. Furthermore, a number of these communities are situated so that their percentage in-

creases in population over the next few decades are likely to be quite spectacular, but unless some drastic modification of these contracts is brought about, it will be Los Angeles which will bear the cost of added capacities and facilities when these must be provided.

Topographically the area east and south of Los Angeles is not readily accessible to the Hyperion outfall. The trunk sewers of the Los Angeles County Sanitation Districts flowing toward the Harbor, however, do serve this outside area advantageously; in fact, some of the southeastern area lying within the city is made tributary to Hyperion only by means of the Manchester pumping plant, although that area is in the natural drainage of the County system.

Population

The great indeterminate factor in the Los Angeles sewerage situation is the rate of population increase. After the census of 1930 revealed that Los Angeles had a population of 1,238,048, the New York *Herald-Tribune* editorialized on "Los Angeles, the Wonder City." No other city in history had experienced such an abrupt concentration of people within a generation and in a situation where precedents do not exist, those who are required to make forecasts of population are beset with the question: "To what extent will the future conform to the past?" The unique aspect of the local situation is that natural reproduction has been a minor factor in the total growth, while migration has and is likely to continue to account for a great proportion of population increments. Bearing on this condition, the following circumstances are significant:

In 1900–10 Los Angeles County received 1 out of 8 persons settling in 11 western states.

In 1910–20 Los Angeles County received 1 out of 5 persons settling in 11 western states.

In 1920–30 Los Angeles County received 2 out of 5 persons settling in 11 western states.

The Metropolitan Area increased from 30,000 to 2,318,000 in fifty years.

Population Growth of Los Angeles

Year	Population	Increase	Percentage in Decade
1880	11,183		
1890	50,395	39,212	350
1900	102,479	52,084	103
1910	319,198	216,719	211
1920	576,673	257,475	80
1930	1,231,730	655,057	114
1940*	1,500,000	268,270	22

* Indicated from U. S. Census preliminary figure, July, 1940.

While the World War temporarily interrupted the trend of population shift toward this region, prior to the census of 1920, that lag was

overcome in the early years of the succeeding decade. The depression of the '30's likewise interrupted the transplanting of large numbers of persons possessing an economic competence although the number of tourists who may later wish to become residents has been reaching new totals. The possibility of war again causing a dislocation of population shifts must be recognized, but the industrial situation of the locality is radically different now than it was twenty years ago, and such a disturbance might not be so great as in the previous war. The fact that several of the largest aircraft factories in the country are located in areas tributary to Hyperion is significant in reference to immediate as well as long-range population changes.

City of Los Angeles. Estimates of Population Growth Prepared by the City Engineer

Year	Population	Increase	Percentage for Decade
1940	1,400,000	168,270	14
1950	1,950,000	550,000	39
1960	2,650,000	700,000	36
1970	3,400,000	750,000	28

It will be observed that the foregoing estimates of population of Los Angeles represent rates of increase substantially less than those which have occurred prior to the decade just closing.

As previously stated the estimated population in 1939 of the 14 communities, not a part of Los Angeles, which contributed sewage to Hyperion was 290,000, compared to 1,300,000 from within Los Angeles (Fig. 3). On the basis of estimates that a population of 4,000,000 would be contributing to the north outfall, its successor conduit and Hyperion in 1970, the division, it is believed, would be 3,180,000 from Los Angeles and 820,000 from the 14 outside communities (Fig. 4).

The estimates in the above table are larger than a number of other similar estimates compiled during recent years and have been criticized because they involve a resumption of the previous trend after a 15 year sideways shift. The uncertainties are numerous and unpredictable as to occurrence and effect, so a dogmatic attitude can hardly be justified. It may be stated with assurance, however, that both the sewers and the disposal facilities of Los Angeles are seriously in need of enlargement or replacement and this work can satisfactorily be undertaken on a progressive construction schedule.

Beach and Ocean Conditions

Following the installation of revolving drum type screens at Hyperion, on the old central outfall in 1924, and on the north outfall as it went into service in 1925, the physical conditions on the adjacent beaches were much improved in contrast to former conditions, but the actual hazards to health have remained and increased. The total removal of suspended solids is 3 per cent, which allows over 200 tons of

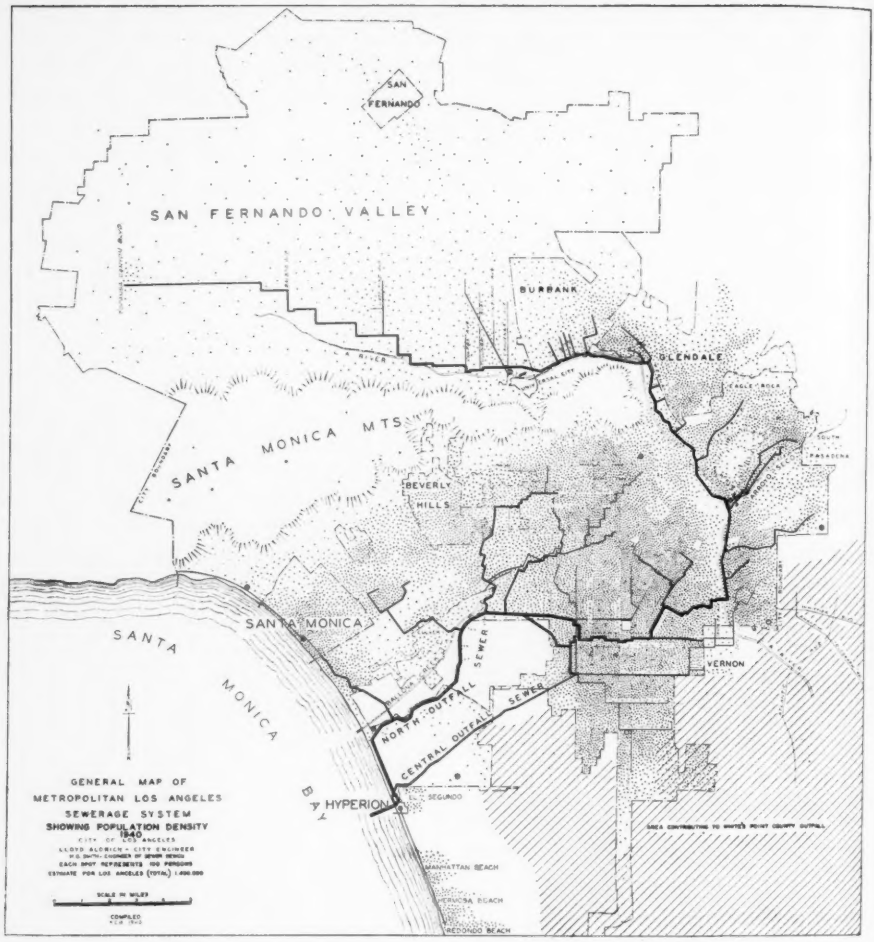

FIG. 3.—Density of population. Each dot represents 100 persons

solids including 12 tons of grease to pass through the screens into the ocean every 24 hours. This filth drifts up or down the coast depending upon the direction of the current polluting some four miles of bathing beach. The State requirements for bathing beaches permit a *B-Coli* count of 10 per c.c. Samples taken at different times show *Coli-Aerogenes* counts of 100 + along a stretch of beach several miles in length. Leaks at the joints in the submarine discharge line, which persist in spite of repeated efforts to stop them, have contributed largely to the contamination of shore waters. The leakage through the defective joints is said to amount to 20 per cent of the flow. The line is 7 ft. in diameter, is 5000 ft. long, and its design capacity was 450 cu. ft. per second. Due to drifted sand through the leaks and the end, its capacity is now believed to be reduced to about 300 cu. ft. per second (Fig. 5).

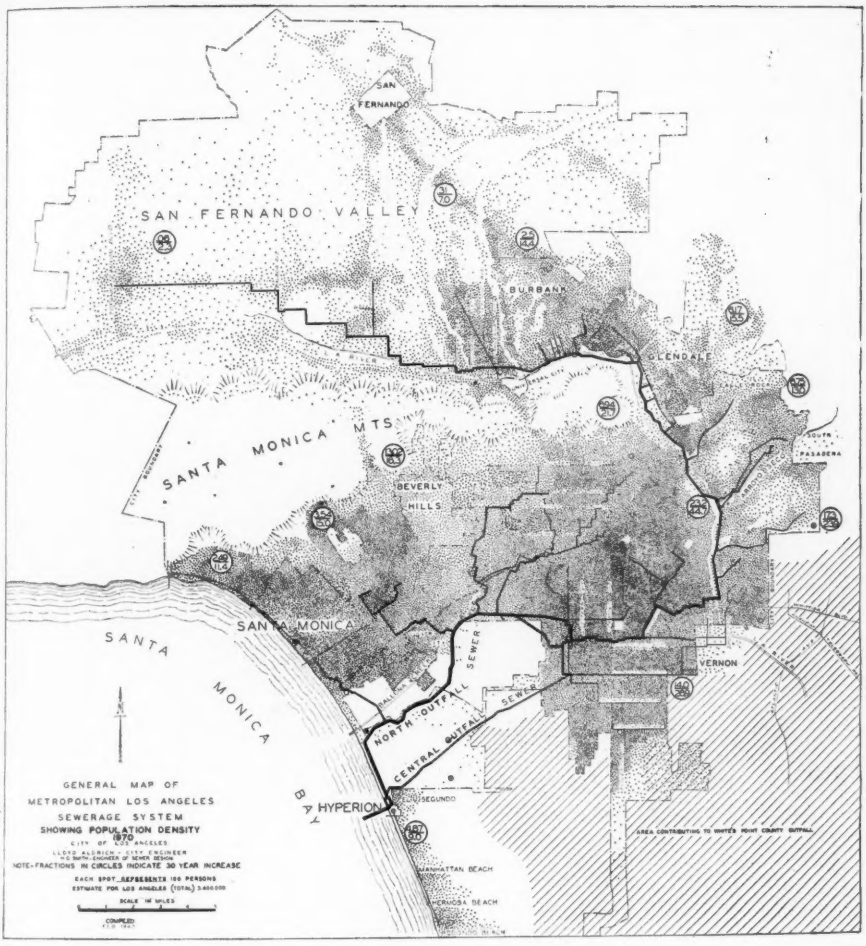

FIG. 4.

As the flow at Hyperion continued to show a progressive increase of approximately 15 c.f.s. per year, there were times in rainy weather when flooding of the screening plant was imminent. In 1933, a by-pass channel around the plant was built to accommodate the flow in excess of 300 c.f.s. and discharge it upon the beach.

QUANTITY OF FLOW

The sewage flow of Los Angeles and the other communities tributary to the Hyperion plant is measured by a recording venturi meter just after it has passed through the drum type screens. On the basis of the 1930 census the average flow represented 80.56 gal. per capita in 24 hours. For the fiscal year 1938–39 it was calculated that the average flow of 130,770,000 gal. at Hyperion was 82.24 gal. per capita in 24 hours.

FIG. 5.—Sleek field from discharge of 5,000 ft. outfall sewer at Hyperion, California. Screening plant is seen on shore in middle of picture. Town of El Segundo is at right.

In consideration of the indicated trend toward slightly larger flows and making some allowance for increased flows from air conditioning installations, it is believed that 85 gals. would be a justifiable figure to use in future treatment plant design for per capita daily flow.

The dry weather peak daily flow at Hyperion is approximately 300 c.f.s. During periods of very heavy rain such as are experienced about one in five years, the peak flow exceeds the 450 c.f.s. capacity of the north outfall sewer and causes it to flow under pressure and to overflow at several manholes elevated about three feet above the conduit.

This condition of surcharged flow during extremely heavy storms exists also in many portions of the city where sewage rises from manholes and spills into the gutters. One cause of this excess storm water in the sewers lies in the fact that there are many storm water inlets to the sanitary sewers in the City of Los Angeles and the contributing communities. These connections, some of which are contrary to city ordinances, comprise downspouts from roofs, yard drains, leaky manhole covers and direct storm water inlets in the streets.

Character of Sewage

The sewage of Los Angeles as represented by analyses of about fifty samples collected at random over a period of three years, is a typical domestic sewage except that the amount of suspended solids is relatively high. Its grease content is normal for California cities whose per capita sewage contribution is about the same as that in Los Angeles.

Approximate Character of Sewage as Received at Hyperion

Determination	Parts Per Million			Pounds Per Capita Per Day		
	Average	Maximum	Minimum	Average	Maximum	Minimum
Susp. Solids, Total	360	960	80(+)	0.24	0.65	0.05(+)
Susp. Solids, Volatile	300	760	80(−)	0.20	0.52	0.05(−)
5-Day B.O.D.	260	420	100	0.18	0.29	0.07
Chlorides	290	530	210	0.20	0.36	0.14
pH	7.3	7.6	6.9	—	—	—
H_2S	10	10(+)	1.5	—	—	—
Ether Soluble (Grease)	50	220	10	0.03	0.15	0.01

Physical Condition of Lines and Works

The central outfall, constructed in 1906, was built of brick. Deterioration caused by the presence of septic sewage resulted in nearly complete abandonment of the line soon after the north outfall was put in service. Portions of the line are in good condition, but it is estimated that an expenditure of about $250,000 will be needed to restore its capacity of 90 c.f.s.

The north outfall completed in 1925 is an unreinforced concrete conduit of horseshoe section lined with tile blocks having cement joints. The extreme inside width is 12¼ feet and the height is 10½ feet. This

section is used on the final 8½ miles constructed on the minimum slope of 4 feet in 10,000. The structure of this outfall is in critical condition in two respects; one resulting from extended longitudinal cracks high up on the sides, and the other from disintegration of the interior. The hazard due to the cracks is particularly great since the line is occasionally subject to flow under pressure. Should a rupture occur, the consequent erosion might impair the sandy loam support of the whole structure for some distance. In recent years nearly one mile of the outfall line has been strengthened by the construction of a reinforced concrete blanket one foot thick over the sewer.

After about ten years of service it was observed that the tile liner blocks were spalling or falling into the line as a consequence of the hydrogen sulfide gas present in the damp sewer. The cement joints and subsequently the concrete itself were attacked by the acid-forming gas. Ventilation of a section of this sewer has recently been effected by the installation of an exhaust fan of 22,000 cu.ft. per min. capacity at a station located a short distance southwest of Centinella Avenue. The results have been very gratifying. The exposed interior surfaces of the sewer within the influence of the fan ventilation are now dry and further disintegration has apparently been arrested. An article entitled, "Experimental Ventilation of the North Outfall Sewer of the City of Los Angeles" by E. G. Studley, giving a comprehensive description of the installation and results is to be found in THIS JOURNAL, Vol. **11**, March, 1939, pages 264–270.

SUMMARY OF CURRENT CONDITIONS

The beaches of Santa Monica Bay are among the most accessible recreational resources available to the people of Los Angeles and vicinity. For recreational purposes, therefore, these beaches and shore waters, if hygienically safe, have inestimable value. Since the time when the first outfall into the Bay was established at Hyperion many years ago, the adjacent beach and the shore waters have been grossly contaminated. The extent of this pollution has been such that significant portions of the beach have been unusable and have been under quarantine by the State Board of Health.

The north outfall sewer, for approximately one-half of the four mile section between Centinela Avenue and Del Rey, is in a critical structural condition with cracks along both sides. Moreover, disintegration of the interior surface has proceeded to an extent which must be regarded as serious. The line from Centinela Avenue to its terminal end at Hyperion is at times overloaded with storm water to the degree that overflow from manholes occurs during severe storms with consequent erosion of its earth cover. Such surcharges took place, for example, in January, 1934, March, 1938 and September, 1939.

The submarine outfall at Hyperion, some 5000 feet long, is also in bad physical condition and for that reason its safe capacity is from 300 to 360 c.f.s., or from about 195 to 230 m.g.d., depending upon tidal elevations, instead of 450 c.f.s., or approximately 290 m.g.d., for which it was

designed. It is stated that the leakage through faulty joints along its length amounts to 20 per cent of its capacity.

Serious overloading of local trunk sewers occurs in many places throughout the city following heavy rains. Badly needed capacity for normal flow and growth is thus preempted.

Issues of the Present Situation

The sewerage facilities provided for and built under the 1922 bond issue of $12,000,000, although monumental in some respects, represent an interim expedient when considered in reference to the future of a large metropolis. The steps preliminary to providing additional outlets for the discharge of sewage or sewage effluent in addition to the single line to Hyperion, now overloaded and creating a combination of nuisance and menace, have yet to be taken. Other supplementary directions of disposal are available, but the delay in their development only afford opportunity for the accumulation of obstacles and resistance. The established right of the City of Los Angeles to discharge sewage into the ocean at Hyperion is an invaluable one, but its benefits could still be utilized in conjunction with a treatment plant of appropriate scope on the shore to correct the present bad conditions.

The physical condition of three important elements of the system presents emergency problems. An extension of the ventilating installation which has proven so effective, offers a demonstrated means of controlling disintegration inside the line and prolonging its life indefinitely. Strengthening of the conduit of the north outfall by external reinforcement is critically needed to safeguard the structure from rupture and consequent flooding of adjacent territory. Even if the conduit is so strengthened it should not then be subjected to flow under pressure. To guard against that circumstance, an automatic overflow gate, to function when normal capacity is reached, has been proposed at the point in the line where it is but a few hundred feet from Ballona Creek. At such flood times the storm runoff in the Creek would provide generous dilution. In March, 1938, the flow in Ballona Creek reached 19,000 c.f.s.

Second: The restoration to service of the unused central outfall would add 90 c.f.s. much needed capacity for present and future flow to Hyperion. It is estimated that an expenditure of $250,000 would place the line in first class condition.

Third: The present restricted capacity of the submarine discharge line is approximately 300 c.f.s. which is no more than the dry weather daily peak flow. A condition exists requiring early correction by construction of another discharge line, its size dependent upon the proportion of the total flow of the system which will be determined to be destined for Hyperion.

A pertinent question is whether present investigations of the city's sewerage system should involve an approximate limit to the volume of sewage which can be permanently discharged into the ocean at Hyperion without recreating conditions which it is now hoped to abolish. Such a limitation of volume at Hyperion as well as consideration of the cost of

conveying increased flows 20 miles or more to the ocean make the possibility of providing inland treatment plants at advantageous locations particularly significant.

The conservation aspects of sewage treatment aside from the reclamation of the beach frontage—which represents conservation of the highest order—would involve the by-products of water, fertilizer and fuel gas. It is possible that these elements may attain importance at some future time. Under immediate prospects the only locality where highly treated effluent could be conserved, would be in an area where percolation of the water would take place readily. By losing identity as effluent and augmenting ground water reserves, a general social benefit would result.

Due to the existence of an impervious clay "blanket" overlying the coastal plain southerly from Vernon and Maywood and westerly from Inglewood and Culver City, spreading of water for percolation into the ground is not feasible in that area. A plant located on any site near the Los Angeles River somewhere between Van Nuys and Universal City would be advantageously situated for spreading of highly treated effluent upon porous areas and would release a moderate amount of sewer capacity for utilization further on.

A treatment plant located south-easterly of Los Angeles in proximity to the river could be made the destination of all that flow in the north outfall originating above the Enterprise St. crossing of the river where the line turns westerly toward the sea. The diversion from the sewer of the already stale sewage would not only reduce the volume, but would have a beneficial effect on the remaining 22 miles of conduit with consequent prolongation of its life. The requirement of this river plant would be mainly to produce an effluent sufficiently stable and of a standard that its addition to the stream would not constitute a detriment to the quality of the flowing water.

Subsequent increase in flow and the necessity for limiting the discharge at Hyperion may create an urgent need for a treatment plant adjacent to the Baldwin Hills so situated that a high grade effluent might be discharged into Ballona Flood Channel.

The requirements of treatment plant sites are such that their early selection and initial use are of vital public interest. Availability of an advantageous site should be utilized in advance of extreme need. The sites should be acquired and sufficient works installed to establish the right to operate, and the opportunity used to demonstrate that freedom from unpleasant and detrimental effects is possible and may be expected.

Los Angeles is now confronted with a sewerage situation which has become increasingly acute during recent years. The opportunity is available to undertake a comprehensive plan of improvement which will be adapted to the unique and diverse conditions existing in and adjacent to the city and toward which steps may be made progressively as the sequence of work is determined and funds are provided.

Appreciative acknowledgment is made of assistance and courtesies received from Mr. Lloyd Aldrich, City Engineer of Los Angeles, Col.

H. G. Smith, Engineer of Sewer Design, and Mr. Floyd M. Darnell, Asst. Engineer, during the preparation of this paper.

Discussion

By Charles Gilman Hyde

University of California, Berkeley

Professor Thomas has presented a very illuminating and adequate review of the trunk sewerage and sewage disposal situation of the City of Los Angeles and its tributary environs. There seems to be little or nothing to add unless it be with reference to the matters of adequacy of provision for future sewage quantities and the cost of treatment and disposal works so involved.

It has been made apparent that there is no single or simple solution of the problem of sewage treatment and disposal for this great metropolitan area. Several solutions are physically and economically feasible and may be argued to be logical. The decision, evidently, cannot be made on the basis of cost alone. The influencing factors are too numerous and too diverse. These factors are psychological and esthetic, as well as technical and financial.

Man has not developed into a prescient animal. As to the past he may have a definite presbyopia but as to the future he is decidedly myopic. Such important things as the determination of the population which must be provided for during the next 30 or 40 years, the cost of money (i.e. the interest rate), the unit costs of construction (i.e. the commodity and labor cost levels), and other significant factors man is unable to forecast with any degree of assurance.

Under the circumstances the wisest program to advocate would seem to be one which will make very ample provision at the outset for all reasonable contingencies. It is an agreeable circumstance, all too seldom realized, to find that the estimates of costs, both of construction and of operation, have been too generous rather than too meager. It is better to have adequate funds with which to build and operate in the best way rather than to discover that the estimates, and therefore the monies available, are insufficient to meet the controlling conditions with maximum effectiveness.

Lands in particular should be immediately acquired in generous areas at logical treatment and disposal plant sites. Excess land holdings can always be sold in future if unwanted. This may generally be done at a premium as compared with purchase values at an earlier date. The truth of this assertion lies in the fact that lands, in general, are appreciating in value within the Los Angeles metropolitan district and will doubtless continue to increase in value for years to come, or until the population density in any given area becomes fixed. On the other hand it is obvious that lands once put to other intensive use can be obtained only with difficulty and generally at exorbitant cost.

Treatment and disposal works should be designed of such flexibility

as related to expansion that their capacity may be increased from time to time as conditions dictate. While this statement is partially true with respect to main conduits (trunk sewers), also, it has less effect here and all such lines should probably be constructed of generous proportions at the outset. The present worth of additional capacity in terms of cross-sectional area is apt to be less than the delayed cost of additional conduit lines, unless such delay is measured in terms of a considerable span of years and/or interest rates are high.

Of the three general projects recently studied and reported upon by the Board of Consulting Engineers, the one which seems to have the greatest merit makes provision for the next three or four decades with a minimum of immediate expenditure. It provides for extensions and additions when such become necessary and defers their construction to that time. Although the annual costs over a 30-year period have been figured with capital expenditures assumed to be made only at the beginning and after 15 years, in the actual case a program of development should be devised which will provide for main sewerage and for sewage treatment and disposal when and as needed.

The project proposes to test the capacity of Santa Monica Bay in the vicinity of Hyperion to receive, without adverse shore pollutional effects, an adequately pretreated sewage and to limit in the beginning the volume of sewage thus treated to one which appears to be logical and safe.

The cost figures for inland treatment works have been set sufficiently high, it is believed, to provide liberally for land areas affording relatively wide buffer strips around the works, landscaped to create parks available for recreational purposes. The funds are proposed to be sufficient to permit of fine architectural treatment of all exposed structures and to control odors to the point of virtual elimination. The Board of Consulting Engineers feels that such demands are worthy of being satisfied even at considerable expense and that no solution of the problem will be satisfactory unless all such esthetic requirements are fully met.

THE COVINA, CALIFORNIA, SEWAGE TREATMENT PLANT *

By Adolf H. Koebig, Jr.

Koebig and Koebig, Consulting Engineers, 458 S. Spring St., Los Angeles

The Covina sewage treatment plant embodies a high degree of treatment for the sewage of a small city using both biological and chemical treatment processes. It is the purpose of this paper to present the difficulties encountered in the building of this plant and to show how these difficulties were overcome by design and operation.

In order to understand how local conditions and public sentiment controlled the design of this plant we must review the history of sewerage in the City of Covina.

History

Covina is a sixth class city incorporated in 1901, is located in an orange belt twenty-two miles east of Los Angeles and has an area of one square mile. The estimated population in 1939 was 3,200 inhabitants. It is bounded on the west and south by West Covina and on the north and east by county territory.

In 1920 there was a great deal of agitation and promotion in the cities in this vicinity to form a sanitary district and join with the County of Los Angeles. Although the City of Covina favored the formation of such a district by a vote of two to one, the issue was defeated in the other cities. In 1923 the citizens voted bonds for the construction of a sewer system at which time many sewer mains and laterals were laid in the city but an attempt to secure disposal facilities was unsuccessful.

The City Council attempted four times during this period to dispose of their sewage, without success. The city owned a 100 acre tract of land five miles to the west near Baldwin Park but a permit from the State Board of Health could not be obtained due to the fact that the people in Baldwin Park objected to having Covina sewage in their vicinity. Another disposal site was selected in an agricultural area to the southwest, lying in the county, which was contested by the City of West Covina.

During this entire time the Los Angeles County Health Department and the State Board of Health continuously complained about sewage disposal in the city by means of cesspools and warned the city that the existing sanitary conditions were a menace to the health of its citizens.

The only sites available to the city for a sewage disposal site were to the north, northeast and southwest in county territory. As the gravity flow is toward the southwest, the sites to the north and northeast were prohibitive on account of high pumping costs. The city found itself with a sewer system partially completed but without disposal facilities

* Presented at the Spring Meeting of the California Sewage Works Association, Avalon, May 20, 1940.

that would satisfy its neighbors. It was decided that if they wanted to complete their sewer system they would have to select a site within their own corporate limits.

Finally a ten acre orange grove with full grown trees at the southwest corner of the city was purchased and annexed to Covina. Opposition of nearby growers and local citizens to the proposed construction of a plant on this site was bitter; however, in spite of this opposition in June, 1939, the citizens voted $60,000 of bonds by a two-thirds majority and procured an allotment from the PWA of $49,090.

The scope of this project included construction of treatment plant, influent and outfall lines, sewer lines in the business area of the city that had not heretofore been constructed and wells for underground disposal of effluent.

The plant design was governed by requirements for

1. Odor control.
2. Sewage to be treated to a high degree of stability to allow percolation in underground wells without contamination.
3. Flexibility of treatment as primary, secondary and complete treatment.
4. Good sludge digestion conditions.

To comply with these requirements the engineers selected a design using two-stage biological treatment with flexibility of individual units, chemical flocculation, rapid sand filtration, sterilization of effluent, odor control and two-stage sludge digestion.

Before construction started persons living in the vicinity of the site filed an injunction case against the proposed plant construction, their contentions being founded on the following grounds:

1—That obnoxious and offensive odors would be given off from said plant to the injury of adjoining properties in this area.

2—That depreciation in value of their properties and of others similarly situated would result.

3—That boron from orange packing plants and laundry would be deposited in the sewer lines and would percolate into the underground water system contaminating their nearby water wells and injuring their orange trees. Also that the wells would be spoiled for domestic use by harmful bacteria in said waters.

4—That the proposed plant was inadequate to take care of the present or future needs of the community and the site was unfitted and not adaptable to the proper percolation of waters through the soil. That the plant would create an unsanitary and unhealthy condition. That the cost of maintenance of plant would be exorbitant and that the plant would not be operated by skilled employees.

Trial of this case, namely, "W. C. King, et al, vs. City of Covina, Case No. 432033 of Superior Court," was started on September 28,

1938. The finding of the Court was that no nuisance had been created, but on the grounds of "HASKELL vs. THE CITY AND COUNTY OF SAN FRANCISCO, Case No. San Francisco 15209" the Court sustained the injunction against possible nuisance. This case was set for trial and all the defendants were represented by Mr. Dailey Stafford, City Attorney of Covina, who was aided in the trial of the case by Mr. Ray Goudey, consulting bacteriologist, and Mr. Adolf H. Koebig, Jr., consulting engineer.

After all the evidence had been submitted by the plaintiffs and defendants the Court made the following findings:

> "That the public health of the people of the City of Covina requires, and there is an immediate necessity for, the construction of a sanitary sewage disposal plant.
>
> That plans and specifications of the City of Covina referred to by plaintiffs herein are adequate for the purpose intended."

These findings were borne out by proof of the following facts:

1—Odors would be absolutely controlled throughout the plant.
2—Construction of the plant in the middle of the orange grove would be remote, and unseen by nearby residents.
3—That sewage treatment and operation of proposed plant would be successful for many years to come.
4—That an ordinance would be provided by the city to prevent packinghouses from disposing of their waste into the sewer system.

Construction work was started in November, 1938, and completed in May, 1939. Following acceptance of the plant by the city, sewer lines were laid in alleys in the business area. Cast iron pipe was used so as to span across the numerous cesspools.

DESCRIPTION OF PLANT

Covina sewage is mostly domestic, plus laundry waste. Design features of the plant were based upon the present population of 3,200 and a future population of 5,000 estimated to produce a maximum flow of 500,000 gallons per day.

The treatment used at Covina might be described as a combination sewage and water treatment process. The treatment process is designed for gravity flow wherever possible, with the plant at a high enough elevation to provide a gravity flow of effluent to any part of the orchard. Treatment consists of screening, pumping to primary clarifier, gravity flow to the primary rock filter and then to the recirculation pump pit. Here the flow is divided by weirs, a portion is pumped back into the primary clarifier and the other portion lifted into the secondary clarifier. Effluent from this tank is further divided into two flows. One portion is dosed with ferric chloride and flows by gravity into the combination flocculating and clarifying tank, while the other portion is

discharged onto the secondary rock filter and then recirculated back to the secondary clarifier.

Overflow from the clarifier-flocculator tank passes through two rapid sand filters, followed by chlorination, with final disposal to the orchard for irrigation or into underground percolating wells.

Application of ferrous chloride for odor control is possible at several vital points.

Sludge from all clarifiers is pumped to two-stage digestion tanks. The primary tank is equipped with a stationary cover and a mixer, while the secondary tank has a floating cover for gas storage. Neither tank is heated at the present time. Supernatant liquor is drawn off the secondary tank and returned to either the pump pit or sludge beds. Digested sludge is drawn off to open sludge beds.

The main operating building houses the raw sewage wet well, dry pump pit, and backwash water storage well in the understructure. A stairway and platform in the wet well facilitates cleaning of the bar screen. Chemical lines run to this pit for chlorine or ferrous chloride application to the raw sewage, supernatant liquor return, and secondary and final sludge returns.

Pumps and manifolds are located in the dry pit. Sewage is handled by two 350 gal. per min. constant and variable speed horizontal, centrifugal sewage pumps, float control mechanism and distribution manifold to any of the three clarifiers. Sludge from these tanks is carried through a manifold to two sludge pumps, one a 4 in. screw impeller type and the other a 4 in. horizontal, centrifugal sludge pump. Filter backwashing is done by a 750 gal. per min. horizontal, centrifugal water pump.

On the ground floor of this operating building there is a small, well-equipped laboratory, tool room, toilet and shower, an exhaust fan from both pits, an enclosed switchboard room and an incinerator on the outside for burning screenings, using either industrial or sludge gas. All electrical fixtures in this building were made explosion proof upon request of the State Industrial Accident Commission.

The recirculation pump pit consists of a collecting channel, weirs, and three interconnected pump pits. Three vertical, centrifugal low head water pumps lift the filter effluents into either primary or secondary clarifiers. Two of these pumps are variable speed while a constant speed pump serves as a standby.

Sterilization, odor control and flocculation are done with chlorine, ferrous chloride and ferric chloride, the latter two chemicals being generated in a Scott-Darcy unit. These units are flexible so that any of these solutions can be applied at several vital points in the plant. Final effluent is sterilized by a separate chlorinator as a protective measure.

Design Data

	Present	Future
Population	3,200	5,000
Flows	0.32 m.g.d.	0.50 m.g.d.

Present flow assumptions not expected to be reached before 1948.

Raw Sewage Pump Pit:
1—50 to 350 gal. per. min. variable speed pump
1—350 gal. per. min. standby pump

Primary and Secondary Clarifiers:
Size each 35 ft. diam. by 8 ft. side water depth
Capacity 61,000 gallons
Detention when circulating twice the maximum design flow at 0.5 m.g.d. (1.5 m.g.d. total) 1.0 hrs.
Overflow rate 570 gal. per lin. ft. per hr.

Primary and Secondary Filters:
Size each 60 ft. diam. by 3 ft. rock depth
Area 2,808 sq. ft. = 0.0644 acre
Quantity filter media 312 cu. yds.
Dosing rate each 1.0 m.g.d. (twice through filter) = 7.8 m.g.a.d. applied load
Size filter media primary 1½ in. to 2½ in.
Size filter media secondary ¾ in. to 1 in.

Estimated B.O.D. applied to filters	625 lb. per day
Estimated B.O.D. in final filter effluent	62 lb. per day
Estimated B.O.D. removed by filters	563 lb. per day
Estimated B.O.D. removed per cu. yd. filter	0.9 lb. per day
Estimated B.O.D. removed per acre ft. filter	1,460 lb. per day

Recirculation Pumps:
Primary 1—200 to 500 gal. per min. variable speed
Secondary 1—300 to 750 gal. per min. variable speed
Standby 1—500 gal. per min.

Clarifier-Flocculator:
Size flocculation compartment 16 ft. diam. by 6 ft. deep
½ hr. flocculation period at 0.5 m.g.d.
Size settling compartment 30 ft. diam. by 8 ft. deep
2 hr. detention period

Rapid Sand Filters:
2–8 ft. diam. sand filters each having area of 50.26 sq. ft.
Design filtration rate 0.7 gal. per sq. ft. per min.
Backwash water pit capacity 15,000 gal.
Backwash rate 15 gal. per sq. ft. per min.
Pumping rate 750 gal. per min.
Waste backwash water is dumped into sewer

Drainage Wells:
3—size 6 ft. diam. by 65 ft. average depth 35 ft. above first water plane
Logs show sandy loam, sand and gravel encountered with intermittent clay and sand stratas
Each well designed for capacity of 35,000 gal. per day

Chemical House:
1—Vacuum type solution feed chlorinator for sterilization of final effluent—Capacity 40 lb.
1—Universal type chlorinator and Scott-Darcy apparatus—Capacity 125 lb. chlorine for manufacturing ferrous chloride, ferric chloride and chlorine

Primary and Secondary Sludge Digesters:
Size each 30 ft. diam. by 20 ft. side—hopper bottom
Total detention time 80 days
Total effective digestion volume 26,140 cu. ft.
Digestion allowance per capita design population 5.23 cu. ft.
Estimated daily gas production 1.0 cu. ft. per capita

Sludge Beds:
Area 3,500 sq. ft.
Per capita design population 0.70 sq. ft.

Plant Operation

Operating results at Covina have been interesting over the short period of less than a year. To date there are about 150 connections out of a present possible 1,000, but one of these connections being a laundry, a waste is provided which requires the complete plant to be run in order to provide the required effluent. Design capacities therefore have not been reached. However, due to the existing long detention periods in the tanks it is expected that by the time the design capacity is reached even greater improvement on the effluent may be expected.

One of the most serious objections to construction of the plant in its preliminary stages, as discussed heretofore, was the problem of odor nuisance. It is interesting to note the absence of objectionable odors at the plant. This can be attributed to several reasons—

1—Absolute odor control at any point.
2—Short detention period in outfall sewer to plant.
3—Small sewage flow with dilution into oxidized sewage.
4—Quick and positive removal of sludges from all settling tanks.
5—Efficiency of operation.

Sewage flow to date has been small, averaging between 50,000 and 70,000 gallons per day. The amount of waste treated is greater as an average of 15,000 gallons per day of backwash water waste has been added to the raw sewage to be treated.

Close check on plant results has been kept by the operator. So far operation of the plant has been directed toward obtaining a perfect final effluent as to both appearance and stability with no series of checks on efficiency of individual units. It was thought at first that the entire plant would not have to be run, but due to the heavy load of laundry waste almost continuous operation of the complete plant is required.

So far it has been difficult to entirely remove the turbidity of the laundry water without final flocculation and filtration, at least to a standard which has been established by this plant for disposal into drainage wells. A few tests have been run, however, to show the degree of treatment in each stage of the plant. The following table shows the average B.O.D. of raw sewage and effluent per month:

	5-day B.O.D., P.p.m.		Oxygen Supplied to Raw Sewage, Lb. per Day
	Raw	Effluent	
November	220	5	1600
December	330	7	2600
January	241	5	1880
February	430	4	3530
March	681	5	—

Results taken during the months of January and February alone gave

Average raw sewage B.O.D.	220 p.p.m.
Primary clarifier effluent B.O.D.	55 p.p.m.
Secondary clarifier effluent B.O.D.	21 p.p.m.
Plant effluent B.O.D.	5 p.p.m.

Due to recirculation of filter effluent at a rate of 2.4 to 1 in the primary stage, the primary clarifier effluent included one part of primary settled sewage and 2.4 parts of partially oxidized sewage. Similar comparison can be made in secondary stage except that the recirculating rate has been about 3 to 1. The above results show a reduction between the secondary stage and the plant effluent from 21 to 5 p.p.m. B.O.D., which is obtained by flocculation with ferric chloride, sedimentation and sand filtration.

Another comparison of plant reduction can be shown from turbidities (using Jackson Turbidimeter) as follows:

	Turbidity Numbers Without Laundry Waste	With Laundry Waste
Raw sewage	800	500
Primary clarifier effluent	51	133
Primary filter effluent	28	38
Secondary filter effluent	under 25	under 25
Secondary clarifier effluent	under 25	under 25
Flocculator effluent	under 25	under 25

(catch samples used)

The dissolved oxygen content throughout the plant has been checked as follows:

Primary clarifier effluent	2.3 p.p.m.
Primary filter effluent	4.5 p.p.m.
Secondary filter effluent	7.6 p.p.m.
Flocculator effluent	7.0 p.p.m.
Plant effluent	7.6 p.p.m.

Suspended solids have not been accurately tested during plant operation as this test has been of little value past the primary clarifier stage. It is estimated from a few tests that the average strength of raw sewage is about 300 p.p.m.

In spite of the dilution in the settling tanks due to recirculation the primary tank has to take a large load of settleable solids since sludges from the secondary clarifier and flocculator are returned to the pump pit and mixed with raw sewage.

Sludge is pumped from the primary clarifier at short intervals with a short pumping period, thereby allowing a thick sludge to be removed. The horizontal, centrifugal sludge pump with variable speed control and the short pumping period have been large factors in successful removal of the heavy sludge. Scum is pumped to the digester through a separate system and pump.

During the six months that operation has been recorded the percentage of moisture of raw sludge has varied considerably but has averaged

about 95 per cent. The system of sludge pumping has enabled a sludge of moisture content from 90 to 92 per cent to be pumped with success, but operating experience has found that keeping the moisture of the sludge about 95 per cent tends to hold the scum off the clarifier surface.

Operation of the two digesters was started by filling both tanks with water and adding sludge daily. This method eliminated both foaming troubles and a high initial gas production, and did not require seed sludge. The table below gives monthly averages of tests at the digester tanks.

Month	Gas. Prod. cu. ft. Day	Raw	pH Prim.	Sec.	Temp. ° F.		Per Cent Moisture Raw Sludge	Per Cent Volatile Matter		
					Prim.	Sec.		Raw	Prim.	Sec.
November.....	1,026	6.8	6.9	6.9	69.6	67.6	96.0	56.5	28.2	24.7
December.....	1,200	6.5	6.8	6.8	64.6	63.4	95.7	62	34	24
January.....	1,230	6.6	6.8	6.8	61.6	59.0	92.4	47	29	25
February.....	1,390	6.8	6.9	6.8	60.6	57.2	95.5	50.5	41	32.5
March.....	1,680	6.9	6.9	6.8	65.8	61.0	95.3	65	42.6	37.5

It is interesting to note the steady increase of gas production since November. Very little of this increase can be attributed to an increasing load on the plant as very few additional connections to the system have been made in the last few months. It might be attributed to increasing temperatures during spring months and to increasing efficiency of digestion. This gas is metered and burned.

Due to the small flow through the plant the design rate of flow through the sand filters has not been reached. For smooth operation so far, each filter is backwashed about once a day and therefore it may be said that this filtration rate is 0.5 gallon per square foot per minute. However, this figure cannot be assumed as a maximum rate. During laundry period a lighter floc is formed thereby causing a much greater load to be removed at the sand filters.

A check of the operating records shows that the effluent has been used for irrigation about two-thirds of the time. The effluent flows into the existing irrigation system for distribution.

The percolation wells average 65 ft. in depth and are lined with leaching brick. The estimated percolation rate from each well was designed for 44 gal. per sq. ft. per day, but during the time that the wells have been used this rate has averaged 60 gal. per sq. ft. per day. The water level has not exceeded 20 ft. off the bottom.

The Covina plant is operated under the supervision of the Water Department and is run very efficiently by one operator, Mr. Verner C. Johnson, with the aid of a part time relief operator.

This plant has proven that sewage plants can be built to provide a complete degree of treatment without being a public nuisance and can be operated at a very economical cost.

Discussion

By R. F. Goudey

Sanitary Engineer, Bureau of Water Works and Supply, Los Angeles

The City of Covina voted a sewer bond issue of $70,000 in 1914 and had to wait until 1940 before its sewerage works facilities were completed. It is doubtful if any other city has had a harder struggle in the matter of obtaining sewerage facilities than has the City of Covina. The writer inspected the first proposed treatment plant site in 1917 as proposed in the original bond issue of 1914, accompanied by Mr. Floyd Dessery, then city engineer. The site was located on Walnut Creek in the midst of walnut groves southwest of the city. The area surrounding the proposed site incorporated forming the City of West Covina specifically for the purpose of defeating the City of Covina in building a sewage treatment plant in their vicinity. The City of West Covina has never carried on normal municipal functions and remains today a community of scattered houses devoid of business, recreational, or residential centers.

In 1922 the city renewed its efforts to obtain sewerage facilities by employing the engineering firm of J. B. Lippincott and Company. A 100 acre site on the San Gabriel River north of Valley Boulevard was purchased for a sewer farm. A satisfactory outfall sewer alignment, however, was impossible to obtain because of right-of-way difficulties. The second attempt, therefore, met with defeat, although the city retained the land which it had purchased.

A third attempt was made in 1925 when Sanitation District No. 7 was formed comprising the greater portion of San Gabriel Valley and including the City of Covina. Covina, as a city, voted five to one in favor of the proposed district. Other cities in the district, however, refused to get behind a subsequent election for a bond issue and the district was dissolved in 1928.

In 1926 a fourth effort was made by Mr. E. P. Dewey, former city engineer of South Pasadena, living at Covina, who advocated an activated sludge plant in the southwest corner of the city much along the line of the Pasadena plant which he had largely designed. His plan, however, failed to win sufficient support by the city trustees.

A complete sewer collection system was constructed in 1930 but could not be used until ten years later. In 1934, Mr. Crawford, city engineer, endeavored to work out a highgrade sewage treatment plant in the southwest portion of the city which can be considered a fifth attempt by the city. At that time Mr. Alva J. Smith was employed to review the plans and later became city engineer.

Mr. Smith recommended a treatment plant be constructed at the formerly selected site on the San Gabriel River. It was possible to

utilize the site this time because the construction of the new Ramona-Garvey Boulevard to Pomona gave direct alignment for the proposed Covina outfall sewer for the greater portion of the distance, cutting the former length from 8.0 miles to 5.6 miles. The firm of Black and Veatch submitted the plans. However, some very serious objections arose over this plan with nearly 4,000 complaints being registered with the State Department of Public Health. The latter held a hearing on March 27, 1935, in Los Angeles. The City of Covina proposed an activated sludge plant of 240,000 gallons per day at a cost of $36,000 designed for 4,000 people, with an operation cost of $25 per million gallons and with final disposal by spreading in gravel beds adjacent to the San Gabriel River. The principal protestants were the California Domestic Water Company and the Whittier Water Company supplying irrigation water to 7,500 acres and domestic water to 11,000 people, with a flow of 15 m.g.d. derived from wells adjacent to the property on which the City of Covina proposed its plant. While the nearest well was 750 ft. distant, it was found that the sewage treatment plant would spread water into coarse sands, gravels in areas where the water table varied from 15 to 50 ft. below the surface and where the material was sufficiently coarse and unconsolidated to cause quite extended travel of underground pollution. The treatment plant itself was located in one of the best water production areas in San Gabriel Valley. A second group of complaints came from people living in the vicinity of the treatment plant as well as subdividers immediately adjacent. While this site in 1922 had been quite isolated, it was now found to be in the middle of subdivision activity. There were 653 complaints from adjoining residents who would be fearful of odors from the proposed treatment plant. The majority of these complaints, however, were without foundation. The city was stopped, in spite of a valiant sixth fight, in its effort to build a sewage treatment plant and subsequently sold the land. In 1936–37–38 the city carried on an almost constant campaign with the County Supervisors, County Planning Commission, and the County Health Department in an effort to locate a treatment plant south and also northwest of the city because at the State Board of Health hearing it had been shown that ground water south of the city was more than 200 feet below the surface and water courses existed where treatment plants might logically be located. None of these negotiations were successful so far as meeting objections of all interested agencies.

In 1939 Mr. Adolf H. Koebig, Jr., was employed to work out a solution to this perplexing problem. After exhausting all other alternatives, he recommended construction of a highgrade treatment plant at the terminus of the previously installed sewer system and selected an adjacent orange grove for that purpose. The site was immediately annexed to the city. Its advantages were as follows: (1) by removing just those trees necessary for the treatment plant itself it was possible to secure adequate isolation as there were no adjacent streets or nearby houses: (2) the area in question was unsuitable for subdivision pur-

poses; (3) the depth of ground water was over 200 ft. with an impervious layer between the ground water table and the surface of the ground and, further, there were no nearby wells which might be in danger; (4) the soil at the proposed site was sandy and suitable for water spreading purposes; and (5) the sewage would be fresh.

Since the site is not located on any stream or storm channel, it was necessary to dispose of the effluent through cesspools at such times that it could not be used for irrigation purposes. The plan pre-supposed that the treatment plant would have to be odorless and the effluent clear enough to be disposed of in cesspools.

An injunction suit was filed by one of the neighbors and a lively court case ensued. Mr. Koebig presented the completed plans which showed that the proposed treatment plant was designed on a very liberal basis; that all odor destruction measures possible were included, such as ventilation and chemical treatment with ferrous iron and chlorine; that long periods of digestion would minimize sludge odors; and that filtration of the final clarified effluent either by irrigation on the orange grove or by disposal into cesspools would result in no overflow into adjoining property. The latter provision was necessary because there was no ditch, drainage course, or stream into which the Covina sewage after treatment could be discharged. The court held that the proposed plans were adequate in operating a treatment plant without an odor nuisance; that there would be no damage to adjacent wells from boron or sewage effluents disposed of underground; and that the underground wells were adequately designed to dispose of all excess waters which could not be beneficially used for irrigation of the orange grove, and denied the injunction.

The city constructed its plant and 26 years after voting its original bond issue it finally obtained sewerage facilities. The City of Covina is probably one of the few cities that has paid 26 years on sewer bonds without having any sewage facilities. It probably is also one of the few cities that has had seven different engineers submit reports and draw up seven different plans for sewerage works.

The writer has inspected the new treatment plant after its completion and has been most agreeably and favorably impressed by its operation. It truly is the most clear and stable effluent of any permanent treatment plant in operation that the writer has ever seen. The present sewage flow is small and there is very little dilution of laundry wastes in the final sewage as it reaches the plant, but no particular difficulty has been experienced in its treatment. As additional sewer connections are made and the sewage flow is increased the sewage will become more normal and easier to treat. The plant, so far as I can see, has met all expectations of the designer, complies fully with the points on which the injunction suit was denied, and is producing a marvelous effluent. This plant is one of the few to be constructed and placed into operation without an avalanche of "bugs" which usually haunts all new plants. Operation costs are not yet available, but they should be within

reason, and when operating at the designed capacity may compare favorably with the combined sewage treatment and water purification costs of similar separate processes elsewhere.

I have been told that people in the vicinity who once protested against the proposed treatment plant are thoroughly satisfied that their fears were without foundation and that there is no desire on their part to further embarrass the city in the matter of their sewage disposal problem.

OPERATING EXPERIENCES IN SEWAGE TREATMENT AT BUFFALO, N. Y.*

By C. R. Velzy, J. W. Johnson and G. E. Symons

Works Superintendent, Asst. Works Superintendent, and Chief Chemist, Buffalo Sewer Authority

Sewage treatment at Buffalo, N. Y., was inaugurated on July 1, 1938. Since that time the many phases of starting plant operations have been of more than passing interest. Some experiences have been particularly gratifying in the successful fulfillment of the design intent, a few have necessitated minor changes and alterations in equipment.

A description of the complete sewage disposal project and the basis of design has been made by Greeley (2) and discussed by Bulger and Velzy (1), Holmquist (4) and Niles (5). Hansen (3) first described the treatment works proper and the equipment. Velzy (9) has discussed some of the early problems of sludge disposal and operating results for the first year have been presented in the annual report (10). Symons, Velzy and Morey (8) have presented and discussed flow diagrams and flow sheets of both the sewage treatment process and the sludge disposal plant together with operating data for the calendar year of 1939 and a discussion of the difficulties of solids balances. Reports have been prepared (6–7) on the accomplishments of the Buffalo Treatment Works as shown by the reduction of the pollution of the Buffalo and Niagara Rivers.

It is the purpose of this paper to present a picture of several of the more interesting operating experiences and problems with a minimum of description and operating data.

Pre-pumping Problems.—One of the important problems confronting the Buffalo Sewer Authority has been the cleaning of sewers, long left uncleaned. Strictly speaking, this problem has not been one of plant operation, but the cleaning program has had its effects on the treatment plant. It is of interest to note from the report to the Board, by Mr. Harold Epstein, General Manager, that up to May 31, 1940, 1,023,043 ft. of sewers had been found dirty and 664,986 ft. have been cleaned. One 8 ft. sewer was nearly full at one point and contained many rocks and much debris. The cleaning of the larger sewers by bucket on a drag line allowed much fine silt to wash on down to the treatment works, affecting several phases of plant operation.

One cleaning project not performed by the Authority had serious effects on the trash racks ahead of the main pumps. Reeds and "cattails" were cut along Scajaquada Creek, a small stream draining 22 square miles. Since the dry weather flow of this stream is intercepted, these reeds were washed into the sewers with the first rain, thereafter. Clogging of the trash racks by the reeds resulted in buckling of the

* Presented at the Spring Meeting of the New York State Sewage Works Association, Syracuse, June 20–21, 1940.

racks due to the pressure of the water. Some strengthening of the racks was done to forestall future recurrences.

Other materials collected by these ¾ in. bars on 5 in. centers have included stones (head size), bricks, a 10 ft. ladder, steel cable, and miscellaneous materials (mainly rags, odd pieces of lumber, tin containers, etc.). For dry weather flow conditions each of the two racks in the inlet structure is cleaned once every ten days to two weeks, in order to prevent loss of head to the wet well. The material removed from the two sections of each rack amounts to from one to two cubic yards. This wet material weighs approximately 2000 to 3000 lb. per cleaning. In storm periods the racks must be cleaned after each heavy run-off.

In the inlet chamber, where the trash racks are located, all electrical appliances are explosion- and moisture-proof. An extensive ventilating system capable of withdrawing 21,000 c.f.m. from the chamber to the ventilating stack minimizes the explosion hazard. On one occasion word was received at the plant that gasoline had reached the sewers from a wrecked tank truck. The inlet chamber was locked and the ventilating system turned on till danger of explosion had passed.

Pumping Experiences.—Any material which passes the trash racks presumably can do no harm to the six main pumps, each capable of raising 120 to 140 m.g.d. approximately 15 to 23 ft. to the sewage conduits. However, during the testing period, it was found that gravel caused excessive erosion of the original bronze wearing rings of the pumps. Wider rings of stainless steel, designed and furnished by the manufacturer, have apparently shown satisfactory wear resistance.

In each rectangular wet well serving three pumps, gravel deposits build up in the corners and along the sides of the well. Portions of these deposits may be picked up by the velocity created by the suction of three pumps operating simultaneously. It is contemplated that the contour of the wells may be changed by concrete fill at some future date to reduce the magnitude of these deposits.

Each pump is equipped with an hydraulically operated butterfly valve and some trouble has been experienced with rags collecting around the shaft and flapper. These obstructions interfere with proper operation. They are removed by hand through a manhole on the discharge line.

The dry weather flow of approximately 110 m.g.d. requires the operation of a single low-speed pump. Average pumpage including storm flow is 130 to 135 m.g.d. The maximum pumping rate has been 560 m.g.d. which required five pumps. On one occasion a pumping rate of 440 to 480 m.g.d. was maintained for a period of eight hours by four pumps.

Consideration of storm flows such as these has led to studies of the relation between wet well elevation, pumping rate and the frequency and magnitude of overflow at intercepting chambers. The objective is to minimize storm overflows while maintaining a reasonable pumping schedule.

Screening Experiences.—In normal dry weather flow, the quantity of screenings is relatively small and it is possible to operate the screens and triturators or grinders intermittently. During storm flows when the screening load is heavy, it is necessary to operate the screening equipment continuously.

In addition to the normal constituents of the screenings, there are a number of items which appear to be somewhat unique in Buffalo. The unusual quantity of rags, towels and articles of clothing may come from the State Mental Institution as has been found at other institutions where it has been reported that recoverable laundry articles approximate 2.5 per inmate per year. At that rate, Buffalo might expect 15 pieces per day. Coarse gravel, some particles of fist size, may come from Scajaquada Creek or from the sewer cleaning operations. Unusual quantities of small pieces of lumber may be due to an extensive WPA program of work which has been done on the sewers of the city.

Certain seasonal effects are noted. In the summer months, large quantities of balls of all sizes are screened out of the sewage. Thousands of corks have been removed in a single day. In the autumn, when the leaves are shed from Buffalo's 300,000 trees, tremendous quantities of leaves are washed into the receivers before they can be removed by the Street Cleaning Department. In both of these seasons, toads and frogs are much in evidence in the screenings. Fish, including several suckers and carp, some over 1 lb. in weight, many bullheads, one large pickerel, 21 in. in length, and a hard-shelled turtle, weighing perhaps 2½ lb., have been taken from the screen recently. Several slimy salamanders from 2 in. to 4½ in. in length have been collected from the screens and the grit; "pollywogs" have been taken from the sedimentation tanks. A 6 in. gold fish, lost from a school, was removed from the screens. The gold fish, several bullheads and suckers, the "pollywogs" and salamanders have been placed in an aquarium in the laboratory where they are fed worms taken each day from the grit.

The operators have followed the practice of removing metal particles, stones and large pieces of wood from the belt before they enter the grinder. Rubber gloves are furnished the operators to prevent possible infection. Routine sharpening of triturator teeth assures production of well ground material, free from stringy fibers.

Experiences with Grit (If it is Grit).—The quantity of material which has been settled out of the grit channels during the past two years may be somewhat high due to the sewer cleaning program (Figs. 1 and 2). On the other hand the organic material which settles out in the grit probably is normal, for it has appeared over the entire period.

It has been somewhat surprising to note that the grit carried considerable quantities of garbage particles. A five-month inventory of the grit samples received in the laboratory indicated that angle worms appeared 77 per cent of the time and the percentages of time that other items were recognizable were, melon seeds (74 per cent), small grains (59 per cent), corn (55 per cent), peas, beans and macaroni (38 per cent), wood splinters, etc. (34 per cent), leaves (32 per cent), etc.

The grit removed is equivalent to approximately 10 parts per million or about 12,000 lb. per day of dry solids. The volatile content of this material averages 38 to 40 per cent. During storms and also following the winter season, when streets are sanded, the per cent of volatile matter in grit decreases. Likewise the particle sizes vary under these conditions. The presence of organic matter in the grit and the lack of a satisfactory dumping area at the plant site indicate the wisdom of the provision for burning of grit. Sieve characteristics and analyses of several grit samples are shown in Table I.

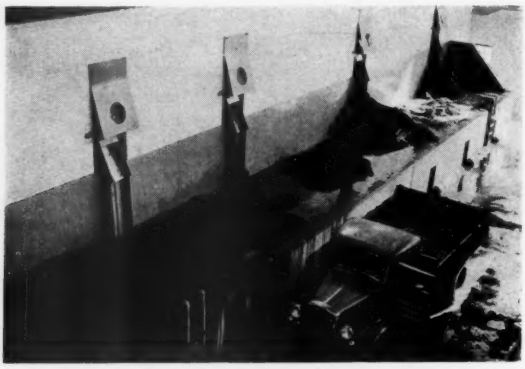

FIG. 1.—Grit production during heavy storm.

FIG. 2.—Removal of grit.

Experiments have been instituted to wash grit before it is discharged into the grit bin and thereby reduce its organic and putrescible content, and improve its draining quality. This washing is accomplished by a chute arranged to cause recirculation of the grit from the elevators back to the grit channel where the sewage flow is utilized for washing purposes. Tentative results to date indicate that the grit quantity may possibly be reduced by the removal of some putrescible matter and fine grit.

TABLE I.—*Analysis of Grit Samples*

Date.....	9/30/39		10/8/39		10/17–25/39		11/11–14/39		3/1–7/40	
Type of Grit	Storm		Storm		Dry Weather Flow		Dry Weather Flow		Dry Weather Flow	
	% of Sample	% Vol. Matter	% of Sample	% Vol. Matter	% of Sample	% Vol. Matter	% of Sample	% Vol. Matter	% of Sample	% Vol. Matter
Mesh Size										
Ret. on 5.	13.3	43.8	17.4	2.0	23.9	63.8	27.7	32.5	12.9	30.5
5–10	7.5	39.8	17.2	26.7	19.2	64.9	15.8	25.2	16.4	32.0
10–20....	16.5	35.9	29.0	23.7	28.7	56.4	23.8	19.8	25.4	35.4
20–40....	31.9	19.0	29.1	18.4	16.1	39.9	23.1	12.2	25.8	10.8
40–60....	21.3	2.1	5.3	6.8	7.5	18.3	8.1	5.8	13.2	4.0
Pass 60...	9.5	10.2	2.0	8.2	4.6	25.3	1.6	12.2	6.3	6.3
Average..		22.2		17.7		52.6		21.2		19.9

Sewage Chlorination.—At the end of the first two years of operation, the Bird Island Laboratory will summarize all routine and experimental data on sewage chlorination collected during that period. At present, it is possible to mention only a few of the interesting highlights.

Chlorine demand of Buffalo sewage varies hourly, daily, with seasons, temperatures, storms, and industrial activity. The average dosage is approximately 5600 lb. per day, but may be as low as 3500 lb. in winter and as high as 8000 lb. in summer. Daily maxima and minima are higher and lower than these values. On one occasion the chlorine demand reached a rate of 63,000 lb. per day for a few hours. Minimum demand has apparently been zero, but this apparent result was due to a false orthotolidin end point caused by some industrial waste.

Sewage odors are controlled by chlorination and ventilation, but even though the residual chlorine content is kept down there is some loss of chlorine to the air in the conduits. Vapors arising from the chlorinated sewage have resulted in condensation in the ventilating system. Analysis of the crystals precipitated from this condensed vapor indicates almost pure ammonium chloride. A study of the corrosion by this condensation on fans and galvanized ducts has been undertaken.

Occasionally some difficulty has been experienced with accumulation of the chlorine impurities called "chlorine taffy" or "chlorine gum," on the chlorinators nearest the battery of five one-ton containers. Pressure reducing valves, lines and control valves in the chlorinators have been plugged. Deposits occur on the inside of the bell jars during these periods. This condition appears when the battery is nearly empty. Control of the rate of withdrawing chlorine has been effective in overcoming this difficulty.

Sedimentation.—Removal of suspended solids in the sedimentation tanks has been considered normal, with an average in 1939 of approximately 45 per cent. In dry weather flows, removal is over 50 per cent. During the early spring months when the sewage flows are relatively

high and the concentration of suspended solids below normal, the removal of suspended solids has been somewhat below the average. This condition has led to statistical studies of the data and experimental work on baffle arrangements, together with float studies, in an effort to increase the removal at these higher flows.

In normal operating routine, the attempt is made to pump raw sludge having a solids content of from 5 to 8 per cent. Although new operators have a natural tendency toward pumping sludge that is too thin, it has been possible, by constant attention, to maintain a sludge of reasonable concentration.

It has happened that during and following some storms a heavy load of solids has been placed on the tanks. Quantities as great as 400,000 to 500,000 lb. of dry solids have settled out in a single day. Sludge removed during storm periods is usually lower in volatile matter content than at other times, and this condition appears to be partially due to the presence of fine sand. In Table II are listed the

TABLE II.—*Sieve Analysis of Sand Taken from Raw Sludge Lines*

Source	Raw Sludge Weir Box	Sludge Pump	Clarifier No. 3	Clarifier No. 2
Mesh Size				
Ret. on 5	0.5	0	0	0
5–10	0.8	0	0	0
10–20	2.0	1.0	0.4	0.4
20–40	2.6	66.0	0.4	3.8
40–60	14.2	25.0	6.4	8.9
60–80	41.7	2.0	17.5	18.0
80–100	18.3	2.0	18.1	21.6
100–150	14.8	2.0	34.8	24.8
150–200	3.1	1.0	13.4	10.8
Pass 200	—	—	9.0	11.7

analyses of several samples of sand taken from the sedimentation tanks and sludge lines. The fineness of these sand particles is such that they cannot be expected to be removed in the grit channels. The presence of this sand in the sludge has, on occasion, caused plugging of the sludge lines from the sedimentation tanks. Back flushing with water usually serves to clear the condition.

Sludge pumps have been equipped with quick-opening sampling valves so that samples can be taken at each pump. This has improved results both from the operator's point of view and the representative quality of the samples.

Skimmings flow from the sedimentation tanks to concrete wells from which they are drawn by sludge pumps and discharged to the sludge tanks. Difficulties were encountered in this operation, but alterations in scum lines to and from the well have eliminated these troubles. These changes involved, (1) facing the scum suction inlet upward at the top of the scum rather than downward at the bottom of the well,

(2) providing means for separating and removing excess water, (3) bringing the flow of skimmings into the well near the scum surface.

The build-up of pressure in the raw sludge discharge line from deposits has been reported by Velzy (9). It is thought that this condition may have been aggravated before the alterations were made by the pumping of large quantities of scum which had been liquefied with steam in the scum wells.

Since making the alterations, steaming of scum in the wells has been discontinued, and there has been developed a scum and sludge pumping schedule which involves pumping sludge and scum at the same time and always at rates that produce reasonable velocity. This pumping schedule, together with the improved method of handling scum, apparently has reduced the tendency toward plugging of the sludge discharge line.

Sludge Tanks.—The importance of sludge tanks in this type of plant is shown by the record of raw sludge removed from the sewage. The removal has varied from 5000 to 500,000 lb. per day (dry basis). It is obviously difficult or impossible to operate dewatering and incineration processes at such widely fluctuating rates. Thus the storage provided by the sludge tanks assures smooth operation of these processes. When grit is burned this point is further emphasized by the wide range (1000 to 309,000 lb. per day) in the daily grit accumulation.

Tank loading is controlled by means of a central box and normally each tank is loaded for an 8 hr. period on a 32 hr. cycle. Withdrawals are on the same cycle. The 32 hr. cycle staggers the loading so that each tank receives approximately the same input of solids and yet has a 24 hr. rest period after solids are added. During a storage and digestion period of five to six weeks the total solids are reduced approximately 45 per cent. Gas production (61 per cent CH_4 and 37 per cent CO_2) averages about 450,000 cu. ft. per 24 hours.

Scum or "top sludge" has always been present in the tanks. It has varied in thickness, averaging 6 to 8 ft. Concentration of scum solids has ranged from 13 to 32 per cent and for the past eight months has averaged above 20 per cent. Volatile matter in the scum averages from 65 to 70 per cent. Attempts to remove this material by pumping through the supernatant lines have met with some success, except at the higher solid concentrations. An effort is being made to reduce and soften the scum by spraying with supernatant liquor or water through specially constructed nozzles located in the gas dome. There is some evidence that this may be successful.

Inventories of the sludge in the tanks are made every month. These are a guide to sludge additions and withdrawals. Samples are taken at two foot elevations from top to bottom of the sludge tanks which are 38 ft. deep at the cone.

In the construction of a depth sampler for this purpose several factors have required consideration including, (1) cylindrical shape of sufficient capacity, (2) weighting and bullet shape to allow easier passage through the scum, (3) a self closing valve that may be easily opened from above the tank, (4) the prevention of fouling of the valve opening

line by using a rubber hose for suspension with the valve chain inside, and, (5) a rig to aid in the raising and lowering of the sampler. Scum is sampled by an augur. A thief sampler for scum has not proved feasible.

The physical difficulties of making the inventories are influenced by weather conditions and the thickness of the scum. Three men required to collect the samples (16 per tank) can complete sampling in approximately 4 hours. Analyses are made of composites of the various layers in the tanks. Total solids, volatile matter, pH, specific gravity, and volatile acids are determined on the composites. Completion of the inventory and analyses requires two days. The ranges of typical inventories of the normal tanks is as follows:

Character	Thickness, Ft.	pH	Volatile Acids, P.p.m.	% Dry Solids	% Volatile Matter
Scum	6– 8	7.5	300–800	25–28	67–75
Supernatant Liquor	8–15	7.3	100–300	0.4– 1.0	50–65
Sludge	0–10	7.2	100–200	5 – 8.0	40–50
Sludge	11	7.1–7.2	100–200	8 –12.0	35–45

Sludge Dewatering.—Digested sludge is pumped from the sludge tank to wells beneath the chemical conditioning tanks which receive the sludge from a bucket elevator. Chemical dosage has varied (2 to 4 per cent $FeCl_3$ and 7 to 12 per cent CaO). With the development of control and more experience of the operators, it appears that chemical dosage is being stabilized at a reasonable figure. Changes in baffle arrangements and provision of visible control of chemical feed may further reduce the quantities of chemicals used.

Under certain conditions when the volatile acids in the digested sludge have increased and the pH dropped below 7.0, it has been possible to condition with $FeCl_3$ alone. This condition is abnormal and has occurred only twice.

Research and experimental studies on sludge conditioning are among the many problems which receive attention in the laboratory. This particular study includes experiments on the determination of the proper dosage, the use of various coagulants, the determination of optimum mixing times and conditions, and the checking of chemical dosage by analysis of the sludge cake.

Sludge dewatering has been particularly successful. The vacuum filters have been capable of dewatering at twice the specified rate and for one day reached a maximum of 13.4 lbs. per sq. ft. per hour. Experiments have been made with different types of filter cloth including wool, canvas duck, burlap and cotton flannel. The teasel on the latter appears to be a factor in making it the most satisfactory material tried.

Plain steel wire is used for winding the filter. The wire is wound on the drum at a spacing of 1½ inch. Use of this spacing as opposed to

the original 3 inch spacing appears to increase the life of the cloth, which is now 200 to 225 hours.

Beneath the cloth is a monel metal screen. After one year of operation calcium carbonate incrustation, due to the alkaline filtrate liquor, had materially reduced the openings of the wire mesh. Mechanical methods of cleaning were of no avail. Acid wash with a 5 to 10 per cent solution of muriatic acid was used. The filter was subjected to this bath for a period of about ten hours. One hundred gallons of commercial acid (20 deg. Baume) were required to restore the screen to approximately the original condition. Incrustations up to one-quarter inch have also occurred in filter lines and filtrate pumps and acid baths have frequently been used to clean the pump impellers.

Incineration.—The drying and burning of sludge has proceeded satisfactorily with the incinerator units meeting the specified rate of 2500 lb. dry solids per hour and with a flexibility permitting comfortable operating schedules. The advantage of sludge storage on one hand and the ability of the furnaces to be heated rapidly to operating temperature on the other hand make it possible to use a six day week for burning. A furnace which has been out of service for two days can be put "on the line" in four hours and a cold furnace can be heated to temperature in about eight hours.

With the sludge cake analyzing somewhat above 37 per cent dry solids and 38 to 40 per cent volatile matter, about 1.2 cu. ft. of gas has been required per pound of dry solids burned. When "top sludge" or scum is drawn from the sludge tanks and burned with sludge the furnaces sometimes tend to overheat and the temperature is controlled by spraying water into the drying tower.

Some difficulties were encountered in the first attempts to burn grit, since both the equipment and process were new. The contractor overcame these difficulties in the development and adjustment of the handling equipment. It was originally expected that one part of grit could be burned with four parts of sludge cake, but in practice it has been possible to burn grit alone for several hours and during one whole month grit and sludge were burned in equal parts.

The greatest problem encountered in incineration has been the abrasion of metal parts of the equipment. This occurs in moving parts handling the sludge such as fans and cage mills and in ducts, cyclones, and pipes through which the sludge travels at high velocity impelled by air. Therefore, the selection of metals for the equipment parts is receiving study.

Experiments with various metals and metal surfacing are being carried on to determine the most economical materials and methods for maintenance of parts subjected to abrasion.

The fuel lines through which the powdered dry sludge (2 per cent moisture) and grit are passed are made of steel pipe. At elbows and bends wear has been excessive. Cost of replacement of the worn parts was prohibitive and welding of steel patches over the holes was expensive and not particularly satisfactory. A shaped wear back (Fig. 3),

made of a steel box, filled with concrete, and clamped to the pipe at the bend has proved to be effective, inexpensive, easy to construct and easy to replace.

FIG. 3.—Wear back on fuel line.

It might be expected that the burning of grit is the cause of abrasion. This is not the case. All of the abrasion troubles were occurring before the burning of grit was adopted into operating routine. The best explanation appears to be the sand present in the sludge. As shown by the data in Table II, the sand which settles out in the sedimentation tank is relatively fine and as mentioned above, the quantity of this sand may be unusually high due to sewer cleaning operations or it may be a normal expectancy due to street sanding operations in winter.

The actual quantity of sand in the sludge cake is indicated by analyses which show that from 28 to 39 per cent of the material is acid insoluble (this may be free sand) of which approximately 66 per cent is SiO_2 and the remainder Al_2O_3.

Sieve analysis have been made on short period composite samples of sludge entering and ash leaving the furnaces. These are shown in Table III.

The drying towers, where hot gases from the furnace are mixed with sludge before passing to the cage mill and flash dryer, formerly were lined with stainless steel plates. These plates became distorted after some period of operation. The buckled liners were replaced with a 2-inch layer of ceramic material which was poured in a wooden form. This material appears to be standing up well.

The original installation of pneumatic equipment for the ash removal system included a cyclone, bag filter and vacuum pump. Because of the high temperature of the ash leaving the furnaces (approximately

TABLE III.—*Sieve Characteristics of Dried Sludge and Ash*

Mesh	Per Cent of Total in Each Classification		
	Dried Sludge	Ash	Fly Ash
Ret. on 5	0.1	0.4	0
5–10	0.4	0.8	0
10–20	3.5	3.8	0.3
20–40	13.6	25.4	0.3
40–60	13.9	24.8	1.6
60–80	12.5	14.7	21.8
80–100	8.8	11.3	14.3
100–150	2.6	3.8	5.0
150–200	9.1	5.4	16.3
Pass 200	35.5	9.5	41.0

1100 to 1300 deg. F.) the bags in the filter were burned out with a consequent plugging of the vacuum pump by ash. For this reason, the contractor substituted a second cyclone for the bag filter and a steam ejector for the vacuum pump. This installation works very well with little maintenance.

All materials received or handled in the treatment works are subjected to measurement and record. In addition to metering of sewage and sludge volumes, sludge cake is weighed on a weightometer. Grit, ash, leaves, trash, clinkers, lime, ferric chloride and oil are all weighed on scales. The scale record shows that in the last eighteen months more than 4200 weighings have been made.

No story of operating experiences can be complete without some mention being made of public relations. In any new plant, particularly, where charges for sewer service are made, the public is apt to be resentful of "sewer rental." Efforts have been made to break down this prejudice by inviting representative groups, organizations and individuals to visit the plant. For individual visitors, watchmen guides conduct tours of the plant and descriptive pamphlets are handed out. Large groups and technical visitors are conducted through the plant by the administrative and technical staff. No record has been kept of the individual visitors but 48 groups of from 15 to 50 persons have visited the plant during the past year. Out of town visitors (both American and foreign) having a professional or technical interest in the operation of the plant have numbered 147 in the past two years.

The maintenance of the roadways and the grounds in the best park tradition has drawn large numbers of automobilists. Parking on the roadways has, at times, become a problem. Since the operation of the treatment plant results in an improved watercourse, the river wall along the plant site is lined with fishermen of all ages. All efforts are directed towards welcoming visitors whether they are interested in plant operation, fishing or driving about the grounds. Efforts to keep the public informed as to the operation and results achieved by the treatment works are made by releasing operating and technical reports to the newspapers.

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SYMPOSIUM ON SLUDGE FILTRATION AND INCINERATION

AUBURN, NEW YORK *

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The treatment plant at Auburn was constructed in 1936 and put into operation on May 17, 1937. It was designed as a chemical precipitation plant, with an average daily capacity of 7.3 m.g. (Fig. 1).

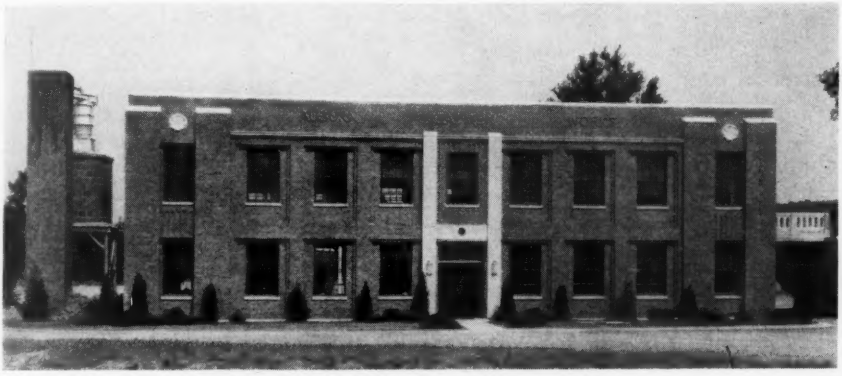

Fig. 1—Auburn, N. Y., Sewage Treament Works.

The plant effluent is discharged into Owasco River and at such times as the flow in the stream is greater than 155 c.f.s. no coagulant is used.

The layout of the plant is as follows in order of sewage flow:

Two combined grit and screen chambers (practically useless as grit chambers).
Four rapid mix tanks.
Four slow mix or flocculation tanks.
Four sedimentation tanks.
One contact tank (for chlorine).

It is the purpose of this paper to describe and discuss problems of filtration and incineration of sewage sludge.

Character of Sludge

The character of the sludge varies greatly according to the season and amount of rainfall. Since the sewerage system is combined and little grit is removed in the grit chambers, a large amount is found in the sludge after a storm. The reason for the failure of the grit cham-

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bers is found in the fact that while the average velocity is about one foot per second the detention period is less than ten seconds, and the grit does not have time enough to settle.

During the summer this grit accumulates in the rapid mix tanks and in the flocculation tanks and eventually stops the mixing paddles and has to be scraped out and hauled away. During the winter the rapid mix and flocculation tanks are by-passed and the grit settles out with the sludge. It becomes packed around the suction pipe for sludge removal and prevents the pump from picking up sludge. Water breaks through and is pumped out while the solid material will not slump and flow into the suction pipe. The only way which has been found to pump this grit and sludge out is to dewater the settling tank and stir the sludge around with a spud as the pump works. Extra water also must be added which makes a thin sludge.

The sludge formed at the time of melting snow generally has a greasy appearance as well as a gritty composition and these two undesirable properties clog filter cloths quite readily.

Another characteristic of sludge in February and March is its tendency to slough off the vacuum filter as it is being picked up and lie in the tank partly dewatered. It has at times accumulated in the filter tanks to the extent that it has overflowed onto the floor. The best way to overcome this difficulty so far is to handle thin sludge (less than 5 per cent solids) and hope for an early spring.

TABLE I.—*Volume of Sludge Removed Monthly*

1938			1939		
Month	Cu. Ft.	Cu. Ft./M.G.	Month	Cu. Ft.	Cu. Ft./M.G.
Jan.	27,596	174	Jan.	27,350	162.5
Feb.	10,817	92	Feb.	24,950	126.0
Mar.	16,230	107	Mar.	20,580	84.2
Apr.	22,033	123	Apr.	10,415	47.7
May	25,775	152	May	36,200	211.0
June	16,469	96	June	44,350	247.0
July	19,700	129	July	44,300	244.0
Aug.	30,000	178	Aug.	49,275	307.0
Sept.	31,170	183	Sept.	53,025	315.0
Oct.	33,100	194	Oct.	43,450	266.0
Nov.	34,000	195	Nov.	37,100	248.5
Dec.	26,750	135	Dec.	23,200	138.0
Total	293,640	1,758	Total	414,195	2,396.9
Mean	24,470	146	Mean	34,516	199.7
The average moisture content for the year was 93.19 per cent.			The average moisture content for the year was 94.37 per cent.		

During the summer, sludge is generally easier to condition and is often highly combustible due to the presence of peas, corn, or squash

from canning wastes. These wastes often affect the pH of the sludge. Of course during periods of low river flow chemical coagulation greatly increases the volume of sludge produced, but does not markedly affect the amount of chemicals used for sludge conditioning.

Sludge Conditioning

Four conditioning tanks are provided on the second floor of the plant into which sludge must be pumped for conditioning. From the standpoint of ease of application of chemicals this is an ideal location, but due to the fact that the filters are on the floor below, too much time elapses between conditioning and filtering, to allow the most economical dose to be used. Time elapsed between sludge conditioning and filtering should be as short as possible after the chemicals have been thoroughly mixed with the sludge. In Auburn, sludge is customarily held from 1½ to 2 hours before the last of the batch reaches the filters and allowance must be made for enough chemicals to last until the last of the sludge is filtered.

Ferric chloride is purchased in solution (45 per cent) in carboys containing 54 lb. ferric chloride on a dry basis, and fed into the sludge by means of a water-operated ejector which dilutes the ferric chloride while impelling it into the sludge tank. This ejector is built up from pipe fittings of stellite alloy.

Originally ferric chloride was purchased in anhydrous condition and fed into the sludge dry by simply dumping it in. This was a highly dangerous and disagreeable task, as well as uneconomical. Changing to ferric chloride solution has meant safer, quicker, more pleasant and more economical handling of ferric chloride. Difference in per cent ferric chloride used in 1938 and 1939 shows a saving of 12.5 per cent of the ferric chloride used due to the change in form, which enables it to be more readily mixed with the sludge to be conditioned.

The conditioning tanks are equipped with mixers which rotate at 12 r.p.m. and are not variable speed motored. It never has made any apparent difference after the chemicals were mixed whether or not the paddles continue to run except that if they stop, heavy sludge settles in the corners on the bottom and does not flow down to the filter.

Variation in dose according to the per cent solids of the sludge is usually obtained by varying the quantity of sludge rather than the amount of ferric chloride dosed. Usually batches of sludge contain from 300 to 400 cu. ft.

An attempt has been made in the laboratory to establish a relationship between per cent dry solids and specific gravity. This relationship appears to vary considerably however, due to differences in the character of the sludge caused by heavy run off, chemical sludge, manufacturing wastes. It is of some help however to take the specific gravity as it gives a preliminary indication of the solid content which is valuable in estimating the necessary chemical dosage.

It has been general practice at Auburn to add the ferric chloride

before the lime, although it doesn't seem to make any particular difference in sludge conditioning which is added first, ferric chloride or lime.

Lime as hydrated lime is used and is purchased in 50 lb. bags and applied to the sludge dry, no better method having been provided as yet. Table II contains data as to quantities of sludge and materials used.

TABLE II.—*Sludge Data*

Mean Values for 1938 and 1939

	1938	1939
Sludge removed—cu. ft. per m.g.	146	200
Mean dry solids—per cent	6.82	5.63
Pounds dry solids—per capita daily	.0914	.106
Ferric chloride used—per cent of dry solids	5.38	4.70
Hydrated lime—per cent of dry solids	14.5	13.0
Filter cake—per cent solids	32.1	31.5
Pounds dry solids filtered—per sq. ft. per hr.	2.44	2.62

A sample of sludge is obtained from each batch as it is pumped up into the conditioning tanks. This sample is taken to the laboratory where it is examined.

The specific gravity of the sludge is obtained first and an estimate of its solid content is made from that based on previous experience. Having estimated the solid content, the chemical dose for that batch of sludge is decided upon. After the batch has been dosed a sample of conditioned sludge is tested in the laboratory for its filterability with a Buchner funnel. After estimating the dose once a day, sludge usually may be conditioned without difficulty for the rest of the day at the same dose. A sample of every batch of sludge is tested for dry solids, however.

In making the Buchner funnel test, previous experience with the sludge being tested is important. There is no particular standard as to how fast the sludge should filter; but the operator can tell, after a few trials, how fast a sludge must be filtered in the laboratory in order to have it work well on the plant filter. The appearance of the filtrate also serves as a guide. A pale pink clear filtrate from the Buchner funnel indicates the best results for the usual sludge in the Auburn plant. This of course is another way of saying that the hydrogen ion concentration must be properly adjusted.

The optimum hydrogen ion concentration varies for different batches of sludge and no definite value can be selected except that to say that sludge fails to filter when the pH value is too low, not when it is too high. However for the sake of economy it is advisable to keep the pH as low as possible with proper conditioning.

If the Buchner funnel test result seems unsatisfactory a batch of sludge may be reconditioned by adding more chemicals before allowing it to run into the filter cradle.

VACUUM FILTRATION

Conditioned sludge flows to the filter cradle by gravity and must be controlled by the operator as to quantity. Two Conkey filters 10 ft. by

10 ft. are used at the plant (Fig. 2). Either filter is capable of supplying filter cake at a greater rate than the incinerator can consume it. The usual production rate is 1500 to 2000 pounds of filter cake per hour.

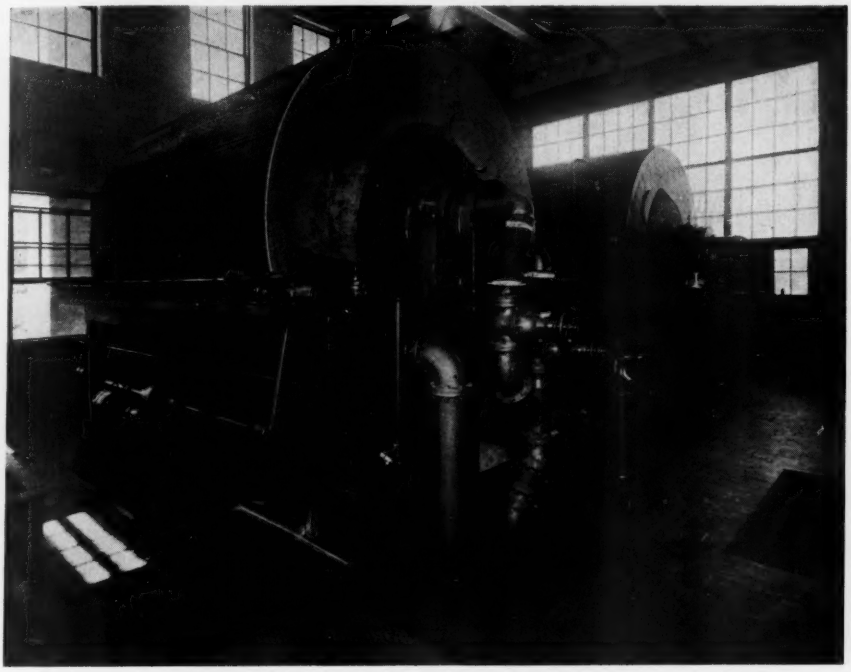

FIG. 2.—Conkey vacuum filters, Auburn, N. Y.

Four samples of filter cake are collected from the filter each half hour when it is running. These samples are weighed on a balance and the weights recorded. A core is then cut from the samples with a cork borer and weighed. The core is placed in an evaporating dish. At the end of a day's run the cores are dried and burned for solid and ash content of the cake. The purpose of weighing the larger sample is to estimate the amount of cake produced. A coefficient has been worked out for each of the filters which when multiplied by the weight of the standard sample gives the pounds of cake per half hour.

MAINTENANCE OF FILTERS

Other than the usual oiling of bearings there has been no repair work done on the filters except replacing the cloth.

Several types of cloth have been tried on the filters, including glass cloth, but the best type for use at Auburn is No. 1 Cotton. A maximum run of 661 hours actual use has been obtained with this type of cloth.

To replace the cloth it used to be necessary to remove and replace 33 half round bars of brass with 17 No. 6 1 in. brass wood screws in

each bar. It was also necessary to fill the screw holes before a new screw would take hold. This job has been reduced by replacing the brass bars with half round soft wood and the screws with finishing nails, using six nails per strip of molding. This change netted a saving of $6.50 in material and 5 hours of labor for four men per cloth.

As the filter cake leaves the filter it drops into a V-shaped hopper in the bottom of which is a screw conveyor which forces the cake through a butterfly feeder into the incinerator.

Incineration

The incinerator is a Nichols Herreshoff, six-hearth, mechanically rabbled furnace. It is 14 ft. high and 10 ft. in diameter (Fig. 3).

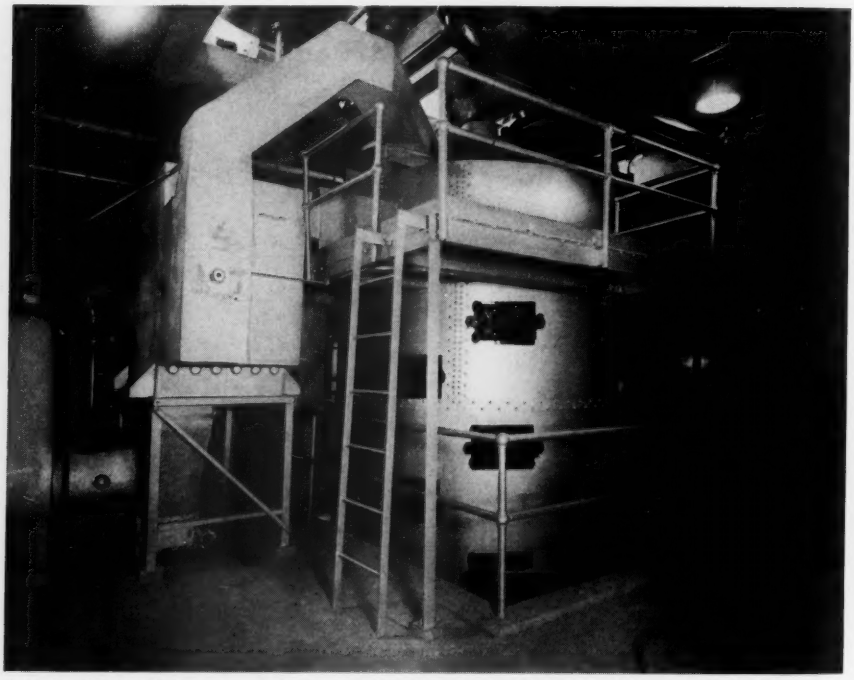

Fig. 3.—Sludge incinerator at Auburn Sewage Treatment Works. (Courtesy Nichols Eng. and Research Corp.)

"Hauck" combination gas and oil burners are installed on Hearths 1, 2, 4 and 6. Gas has been used entirely in operation so far.

Thermo-couples at Hearths 1, 2, 3 and 4, at the flue gas fan, and at the combustion air fan are connected to a pyrometer to show the temperatures at these points.

Filter cake is fed into the top of the incinerator and the hearths are numbered from top to bottom. Rabble arms attached to a revolving central shaft sweep the sludge off each hearth to the one below it. The

material on Hearth 1 is pushed to the center of the furnace where it drops through an opening concentric with the central shaft. The teeth on the rabble arms of Hearth 2 push the cake to the outside edge of the hearth where it drops over to Hearth 3. Hearths 1, 3 and 5 are "in" hearths and 2, 4 and 6 are "out" hearths.

Hearths 1 and 2 are drying hearths and the temperatures range from 1000° F. on No. 1 to 1450° F. on No. 2. If these temperatures are maintained the cake is dry and ready to burn when it falls onto Hearth 3 where the temperature is about 1580° F. After passing Hearth 3 the temperatures drop from 1400° F. on Hearth 4 to 500° F. on Hearth 6.

From Hearth 6 the ash is discharged through an opening into an inclosed steel box which holds about 500 lb. of ash, although it is never allowed to get full. The ash is removed from the steel box by an ash conveyor.

Difficulties and Remedies

From the time the plant was first put into operation there was trouble with smoke being discharged from the incinerator, filling the building with fumes. This condition occurred when cake was burning with a flame on Hearth 4, and its cause was overloading. Soot was being carried over from the furnace into the preheater where it clogged the passageways in the hot air element and prevented the flue gas fan from pulling out the gases and smoke from the furnace.

High pressure air was used to clean out the preheater and this was satisfactory until the elements became warped from excessive temperatures caused by heat from the top hearth which was produced during burning off or shut down periods when temperatures sometimes reached 1500 to 1700° F.

The solution of this problem proved to be the removal of the preheater. The results obtained were the almost complete elimination of escaping smoke and gases. The capacity of the incinerator also was increased. The preheater was removed in November, 1938. The rate of burning of dry solids for the ten months before November, 1938, was 364 lb. per hour. After removal of the preheater the rate of burning in the following ten months was 395 lb. per hour—an increase of 8.8 per cent.

In November, 1939, at the suggestion of a representative of the incinerator manufacturer, the preheated air fan located at the top of the central shaft was removed. This fan picked up air not only from the central shaft but also from the atmosphere outside the incinerator. The effect was to reduce the temperature of the air entering the incinerator for combustion from 500° F. to 200° or 300° F. With this fan removed and a direct connection made to the gas burners on Hearths 1, 2, 4 and 6 with surplus air going to Hearth 6 for combustion air the temperature of this air at the bottom (Hearth 6) hearth rose to 400° to 450° F.

This fan and the preheater in the original installation had the effect of counter-balancing each other as to temperatures produced. With

the removal of the preheater, the fan became unnecessary either for cooling effect or for driving air.

As a result of the increase in temperature of air introduced for combustion the capacity of the incinerator was increased for the month of December, 1939, to an average of 614 lb. of dry solids per hour. During this time one run of 85 hours shows an average of 706 lb. of dry solids per hour. This means an increase in rate of burning up to 79 per cent.

Prior to making the above changes in the incinerator the ratio of dry solids per hour burned to that filtered was 364 to 804. After making changes noted above the ratio is 706 to 804 with prospects of the incinerator capacity showing an increase as time goes on. The rated capacity of the incinerator is 500 lb. dry solids per hour.

Unfortunately up to the time of writing this paper, insufficient sludge has been handled to get a fair comparison of power and fuel costs per unit of sludge handled, but we believe that a substantial saving in those two items will be shown this summer.

However this comparison of gas consumption may be shown:

1938—gas for fuel, 4220 cu. ft. per ton of dry solids.
1939—gas for fuel, 2400 cu. ft. per ton of dry solids.
1940—gas for fuel, 800 cu. ft. per ton of dry solids.

Note.—Preheater removed, Nov., 1938, upper fan driven by 3 h.p. motor removed Nov., 1939. 1940 figures are for only one run of 59¼ hrs. All figures include gas consumed in heating the incinerator prior to burning the sludge. 1940 figures are for plain sedimentation sludge only.

Since the preheater acted as a cooling device for gases leaving the incinerator, its removal meant an increase in temperature of the flue gas fan and it was replaced by one of stainless steel.

This fan could be eliminated by increasing the height of the stack from its present height of 33 ft. to 49 ft.—an increase of 16 ft.

A new section of central shaft which extends between Hearths 2 and 4 has been installed and the shaft and rabble arms on Hearths 3 and 4, and shaft on Hearths 1 and 2 have been insulated. The insulation used was "Fire Crete" about 3 in. thick fastened on by spot welding ½ in. rods to the shaft as studs and making a web of nichrome wire to hold on the insulation.

Sludge Pumps

Sludge pumps are as follows:

Two duplex Carter sludge pumps—rated capacity 75 gal./min.
Two simplex Carter sludge pumps—rated capacity 50 gal./min.
One Chicago Screwpeller pump—rated capacity 75 gal./min.

Valve seats of the Carter pumps were originally composed of rubber and canvas, but were not durable and were replaced with brass. These brass seats are very satisfactory.

The original brass plungers were replaced with cast iron which after a year and a half of wear show little depreciation. These plungers are brushed with Gulf gear oil which forms a thin film on the plunger barrel giving satisfactory lubrication.

Ash Conveyor

The ash conveyor is an enclosed air system operated under a 6 in. vacuum caused by a Roots blower driven by a 25 hp. motor. The ashes drop into a steel container under the incinerator from which the conveyor system picks them up and conducts them to a 10-ton elevated tile tank outside the building from which the ashes are drawn away by truck every few days. The system must be operated at 15-minute intervals during the burning period and is started manually.

An air washer is installed in the return air line just above the Roots blower which is at the end of the line. The purpose of the air washer is to remove ash which has been carried over with the air from the outside tank to prevent the ash from clogging the blower. The air washer consists of a conical shaped tank, point down, with the air entering through the side near the top through a hose which extends into the tank to the edge of a funnel of sheet iron. Water is sprayed down from the top of the tank through the air as it passes over the top of the funnel and out through the outlet pipe at the top of the tank on the side opposite the entrance. The water drops through the bottom of the funnel through a screen and is ejected to a sump well.

The air washer has to be cleaned daily when in use to prevent the ash, which is removed from the air by the water sprays, from building up on the funnel and clogging the entrance pipe.

The manufacturers of this equipment have proposed to remedy this condition by installing a coke filter in the washer and changing the entrance point to the bottom thus drawing the air upward through the filter. The water would be turned on after the apparatus has been operated each time to wash the accumulated ash down to a concrete tank with overflow to a sump well. This change appears feasible but costly and would not overcome other troubles yet to be mentioned.

Moisture frequently enters the ash pipes and causes the ash to accumulate and clog the pipes which must be then taken apart and cleaned.

Another annoyance is the dust nuisance which occurs when the ashes are drawn away. Although a chute conducts the ash directly to a truck, dust is unavoidable and it spreads over everything for several hundred feet around.

With these troubles still to contend with, it seems probable that some other complete method of ash handling may have to be adopted eventually.

Co-operation of Manufacturers

Changes made in equipment have usually been made with the advice and co-operation of the manufacturers and no criticism of anything installed in the Auburn plant may be applied to similar equipment in another plant, since situations differ and each installation is a problem in itself.

ELMIRA, NEW YORK*

By G. J. McInerney

Chief Operator, Sewage Treatment Plant, Elmira, N. Y.

At the Elmira, N. Y., Sewage Plant (Figs. 1, 2, 3), sludge pumps convey the sludge from conditioning chambers, which are located below, to the sludge weir box in the filter room. From the sludge weir box,

Fig. 1.—Elmira, N. Y., sewage treatment works. Front view.

after the introduction of ferric chloride and subsequent paddle mixing, the conditioned sludge (lime having been added in the conditioning chambers) flows by gravity to the rotary vacuum filters of which there are two. These units have an effective filter area of 200 sq. ft. each and dewater 6 pounds of dry solids per sq. ft. per hour at maximum rate.

Dewatered sludge is carried to the incinerator by means of an endless belt running between the filters. A four-hearth, oil burning incinerator reduces the sludge to non-offensive ash and has the capacity to incinerate one-half ton, dry basis, of chemically precipitated sludge or one-quarter ton, dry basis, of raw sludge per hour. Ashes are removed by a vertical bucket lift and discharged into an elevated bunker on the outside of the building.

* Presented at the Spring Meeting of the New York State Sewage Works Association, Syracuse, N. Y., June 20–21, 1940.

Unsatisfactory experiences in mixing anhydrous ferric chloride and handling the resulting solution taught us the folly of purchasing the chemical in this form. These experiences ranged from the staining of the walls and flows from leaky supply pipes or mixing tanks to the straining of tempers when one's clothes started to disintegrate and fall off after attempting to open a plugged supply pipe. So it was with few regrets that we made the change from purchasing the anhydrous salt to purchasing the liquid form (12 gal. carboys). This change was made more attractive when we were quoted a price on a dry basis for the "liquid iron" that compared very favorably with the "anhydrous iron."

FIG. 2.—Elmira, N. Y., sewage treatment works. Sedimentation tanks.

In the early days of operation we felt that there would "never be a dull moment at a sewage plant." However we have long since settled down to a steady, if less exciting, routine. Some of our early troubles might be described as follows.

Since the plant is equipped with a dry feeder and slaker unit for handling of lime, it had been the practice to rely solely on the automatic controls in filling the hopper which is suspended above the feeder. Our faith in this system had been proven by nearly three years of operation when one Sunday morning much to our dismay we discovered our dry feeder and slaker unit covered with a large quantity of quicklime and the hopper above empty. Undoubtedly the lime received in the last car had been a little "off" the proper size and in mixing with what remained of the previous car had developed an arch just over the discharge opening which was dislodged by some unusual jar. Our remedy for this condition has been to check the physical properties of the lime more closely and to fill the hopper about one-third full.

We have noted a considerable saving in the use of ferric chloride for sludge conditioning since applying this coagulent continuously to the sludge as it flows through the mixing chamber immediately before it reaches the filter tub. Formerly we added ferric chloride as well as lime to the sludge in the one "batch mix." Increasing the usual quantity of lime by 20 to 25 per cent will often clear up any difficulty the filter operator may have with grease, particularly if the grease is of animal origin.

FIG. 3.—Elmira, N. Y., sewage treatment works. Main switchboard.

Have you ever been in a filter room when the operator is in the best of spirits? Sludge conditioned perfectly as evidenced by a nice cake, heavy but dry, rolling off the vacuum filter. Temperatures are up and the old incinerator is just begging for more—than like a bolt from the blue, all the forces of evil seem to "gang up" on the poor fellow and bedlam breaks loose. Well, what happened? Listed here are a few hypothetical possibilities:

Finding the sludge pumps that are used to charge the filter tub plugged, and unable to find his helper at that moment, the operator decides to correct this difficulty himself and trots down to the pump room, allowing the filter to run in his absence. Upon returning to the filter room he immediately starts the sludge pump to charge the vacuum filter, since the sludge level in the same is now rather low. In the meantime unknown to this harrassed gentlemen in the filter room, since he

hasn't had the time nor the opportunity to glance at the gauge, the vacuum starts dropping with a resultant filter cake that contains more moisture and is more tacky than usual. Suddenly in the midst of his woes he looks up to the top of the incinerator and finds that a large section of the moist filter cake, failing to break, as a drier cake would have done, as it drops from the filter drum has been deposited across the mouth of the sludge cake feeder hopper (hopper used to convey sludge cake into incinerator) and the sludge is now spilling over onto the top of the incinerator. Well, not wishing to interrupt the flow of filter cake to the incinerator for a longer time for fear that to do so would cause the incinerator temperatures to become unbalanced, the by now breathless operator rushes up to the incinerator top and corrects the trouble by means of few well directed thrusts with a staff left there for that purpose.

Now what is that dripping, splashing sound, sound of impending tragedy? The filter tub is running over. (Yes, they do run over despite overflow pipes.) He forgot to turn off the sludge pump before he ran to the top of the incinerator. After easing his mind with a few pointed remarks concerning the maintenance man or his helper wherever he is, the operator uses the broom and hose for some few minutes and hopes that his troubles are about over.

Since the above situation was one of conjecture in its entirety, the chances of such a chain of hectic events occurring in any filter room would be nil. However, if analyzed one by one they are worth consideration.

Sludge pumps regardless of type or manufacture occasionally cause trouble. The frequency with which the trouble occurs depends principally upon whether choice of pump was based upon a thorough understanding of the characteristics of the various types of pump and an appreciation of factors involved in the proposed location, or whether the only consideration was the price tag.

The operation of supplementary vacuum filter equipment, the vacuum filter, the incinerator and the maintenance of these units are closely interrelated. Some authorities say that incinerator operation is controlled almost entirely by the operator of the vacuum filter and the converse of this statement is also true. Loss of vacuum as usually experienced (eliminating pipe and joint failures) occur either in the vacuum receiving tank-filtrate pump system or in the vacuum system around the periphery of the drum. In reference to the former a rising of the filtrate level in the vacuum receiving tank (unit where the vacuum and filtrate separate) would automatically open the vacuum breaking valve, which is used as a protection for the vacuum pump. This is caused by a reduction in the efficiency of operation of the filtrate pumps. At some plants a deposit resembling boiler scale on the inside of the pump causes this reduction in pumping efficiency. This scale undoubtedly is precipitated by the lime used in conditioning the sludge, but in most cases a reduction in the amount of lime as a corrective measure is prohibited by the fact that such reduction interferes with sludge

conditioning. To date the most practical relief measure has been the frequent cleaning of the filtrate pumps. The installation of a sight glass on the vacuum receiving tanks affords a positive means of detection of this trouble in its earliest stages. Failures in the cloth or the drying out of the wooden decking from periods of long idleness account for the vacuum failures in the filter itself.

Size reduction of filter cake before it enters the incinerator can often be accomplished by welding a number of knives or cutters to the lower half or supporting plate of the doctor knife.

Carbon formation in the burner pockets is a problem at some plants. Re-aligning the burners so that the flame does not impinge on the refractory lining of the burner pocket, but is concentric with the opening into the incinerator proper, is of considerable help. The incorporation in the oil and air lines of patented valves that close on the oil pipe whenever the pressure drops in either line are of considerable help. Such installations prevent the formation of oil pockets and the subsequent charring of the same.

Costly repairs can be eliminated and good incinerator operation can be insured if the operator is thoroughly familiar with the function, operation and some of the more important construction details of the preheater. Most operators find that if the openings between the preheater elements can be kept clean their troubles will be kept at a minimum. They also find that a draft gauge inserted in the flue between the preheater and the stack will show them when it is necessary to use the air compressor for removing ash from between the individual envelopes or elements of the preheater. Since it is characteristic of most incinerators to have the temperatures rise progressively on the upper hearths if the supply of fuel is stopped, most operators have protected their preheaters from excessive temperature by means of an accurate temperature (recording type preferred) measuring unit and in some instances have installed an automatic water spray system in conjunction with the temperature measuring device.

TOWN OF GREECE, MONROE COUNTY, NEW YORK*

By William D. Denise

Superintendent, Sewage Treatment Plant, Town of Greece, N. Y.

The treatment plant of the town of Greece is an activated sludge plant with a designed capacity of 1,000,000 gallons per day to serve a population of 10,000 persons. The plant and sewerage system were put into service in July, 1938. At the present time the plant is serving a population of 5800 persons with an average flow of 420,000 gallons per day.

The plant embodies the following units: two grit chambers, comminutor, primary tanks, down draft aerators, final clarifiers with mag-

* Presented at the Spring Meeting of the New York State Sewage Works Association, Syracuse, N. Y., June 20–21, 1940.

netite filters, hopper bottom sludge storage tanks, chlorinators, vacuum filters and an incinerator.

The surplus activated sludge is wasted to the channel carrying the raw sewage and is settled out in the primary tanks with the primary sludge. It is then drawn to the sludge storage tanks. Ten days are required to concentrate and fill the sludge storage tanks. When they are

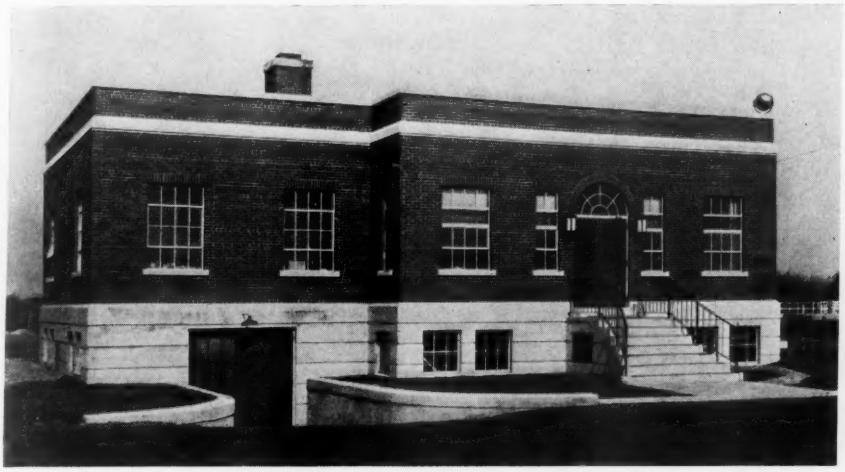

FIG. 1.—Town of Greece sewage treatment plant process bldg., housing offices, laboratory, vacuum filters, incinerator, pumps, etc.

filled the incinerator is heated and the sludge is dewatered and burned.

This discussion of the sludge filtration and incineration at our plant will begin with the conditioning of the sludge prior to dewatering.

From the time the plant was put into operation (July, 1938) until May 1, 1940, anhydrous ferric chloride was used, a carload of 36,000 pounds having been purchased in November, 1938. A 150-pound drum of anhydrous ferric chloride was dissolved in a rubber lined tank with a 48 gallon capacity, making a 38 per cent solution. The solution was then drawn by vacuum to the storage tank near the ceiling of the chemical room. From there it was fed by gravity to the feeders and thence by gravity to the mixing tank. When the powder was dissolved the temperature of the solution reached approximately 170° F., and after 6 hours (the usual amount of time required to empty the storage tank) it still maintained a temperature of 140° F. These high temperatures softened the hard rubber piping and feeders which caused leaks and warping of the feeders and ultimate failure.

Liquid ferric chloride of 40.5 per cent strength on the anhydrous basis is now used; this solution comes in 12 gallon carboys; each carboy contains 48.6 pounds of ferric chloride on the anhydrous basis. The contents of the carboy are diluted to a 15 per cent solution before being drawn to the storage tank. Although this solution has not been used long enough to give it a fair trial, I feel that it is going to be much

easier to handle, cheaper and easier on the equipment. Moreover due to the weaker solution a lower dose of ferric chloride per pound of dry solids will be required.

I should like to say a word about the method of drawing the ferric chloride to upper storage tank which is a tightly closed tank. The

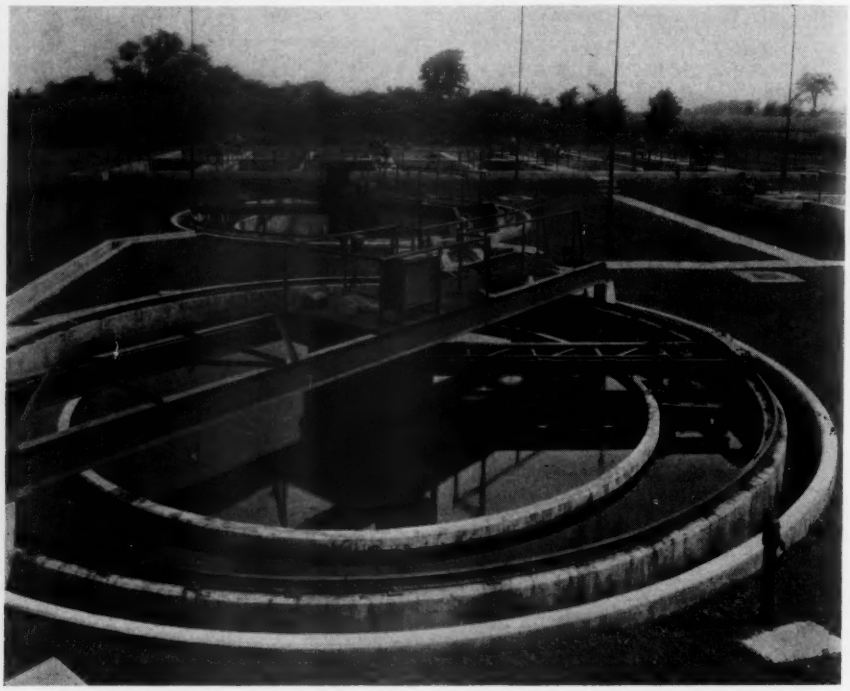

FIG. 2.—Town of Greece sewage treatment plant, final tanks with magnetite filters, aerators in background, primary tanks on right.

vacuum is taken from the line to the filters and the lift is 11 ft. 2 in. This system has given no trouble as yet and does not rob the filters of the needed vacuum during operation. The greatest advantage of this method is the elimination of pumps which give considerable trouble at times. The only precaution necessary is the provision of a storage tank large enough to take the contents of the dissolving tank so that the solution will not be drawn into the vacuum lines and the filtrate pumps.

The lime feeder is a dry feed machine with the lime going into solution as it leaves the machine, and flowing by gravity to the mixing tank. With the exception of a clogging in the piping to the mixing tank no trouble has been experienced.

The sludge mixing tank is 7 ft. by 5 ft. by 3 ft. 8 in. deep and is divided into two tanks by a partition running lengthwise. Each tank is again separated into three compartments by two over and one under baffle plates. The tank was originally equipped with three air diffuser

tubes for mixing the sludge and chemicals, but has since been equipped with a paddle agitator driven by a ¾ hp. gear reduction motor and the paddle agitator revolved at the rate of 6 r.p.m. The mixing of chemicals and sludge by this method is very complete and far superior to the mixing with diffuser tubes.

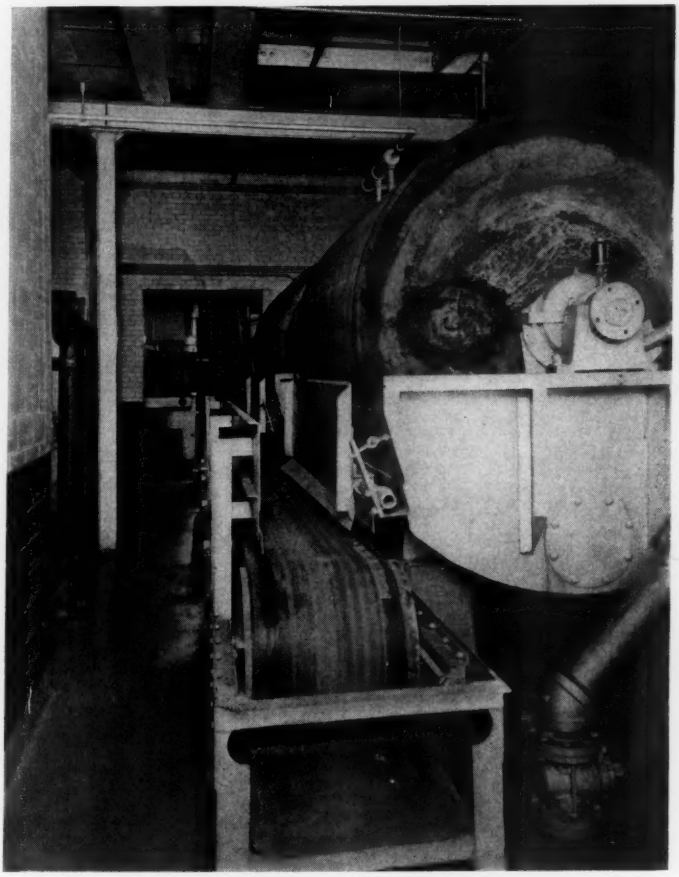

FIG. 3.—Town of Greece sewage treatment plant, vacuum filters.

The conditioned sludge has an average pH of 10.9 and flows to the filters by gravity, the level in the hopper being maintained by a float switch in the mixing tank. There are two 5 ft. 4 in. by 6 ft. Oliver continuous vacuum filters with a filtering area of 100 sq. ft. each. We have used wool cloths, cotton flannel, and cotton without nap. The latter was very unsatisfactory to our conditions, the cloth blinding within the first six hours of use. A wool cloth will last approximately 300 hours while a cotton cloth will give good results for about 130 hours. As a wool cloth costs six times more than a cotton flannel cloth, we feel it is better

to use the flannel type. We are doing this with good results. A wool cloth will, however, lower the moisture content of the filter cake by 3 or 4 per cent more than the cotton. When the sludge is properly conditioned the filters give little or no trouble. It is necessary to stop the filters about every 8 hours during a run and clean the cloth with the sprays. This operation requires about 10 minutes.

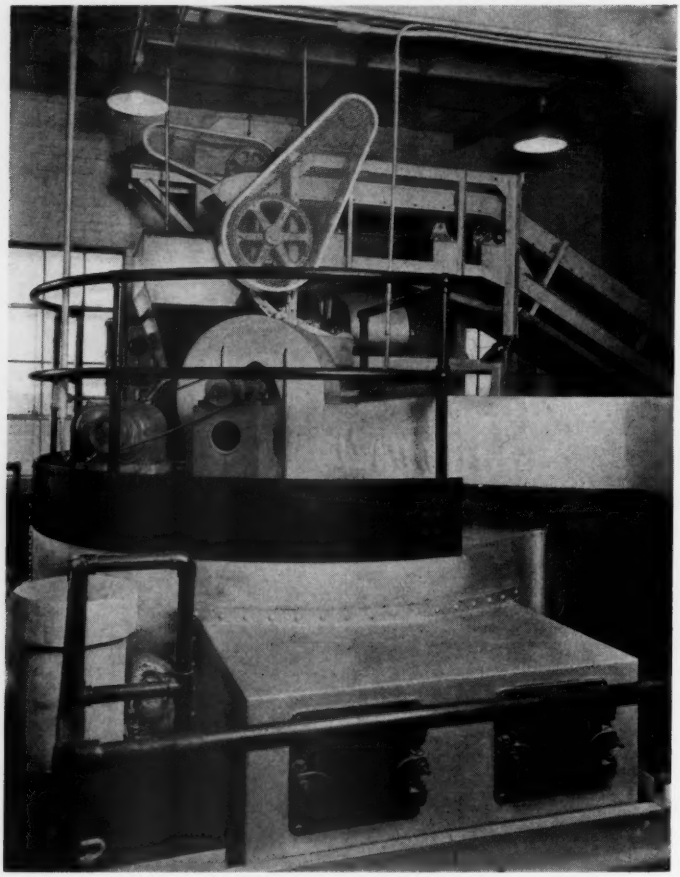

FIG. 4.—Town of Greece sewage treatment plant. Upper part of incinerator.

The moisture content of the filter cake averaged 74.6 per cent for 1939, with a maximum of 78 and a minimum of 71. The drum averages 10.5 revolutions per hour being submerged about 8 in. in the sludge. As the capacity of the incinerator is 30,000 pounds of filter cake per 24 hours, or 1250 pounds per hour, the weight of cake to the incinerator has to be governed at the filter. The average thickness of the filter cake is 5/16 in., and with a moisture content of 75 per cent the average weight will be between 1250 and 1350 pounds per hour. The cake leaves the

filters dropping upon an 18 in. belt conveyor and is carried either to the incinerator or to the hopper on the outside of the building.

The incinerator is a Nichols Herreshoff six-hearth sewage sludge incinerator. At first considerable trouble was experienced with the sludge plugging up on the top hearth. Every other tooth in the rabble arms was removed and since little or no trouble has resulted. The in-

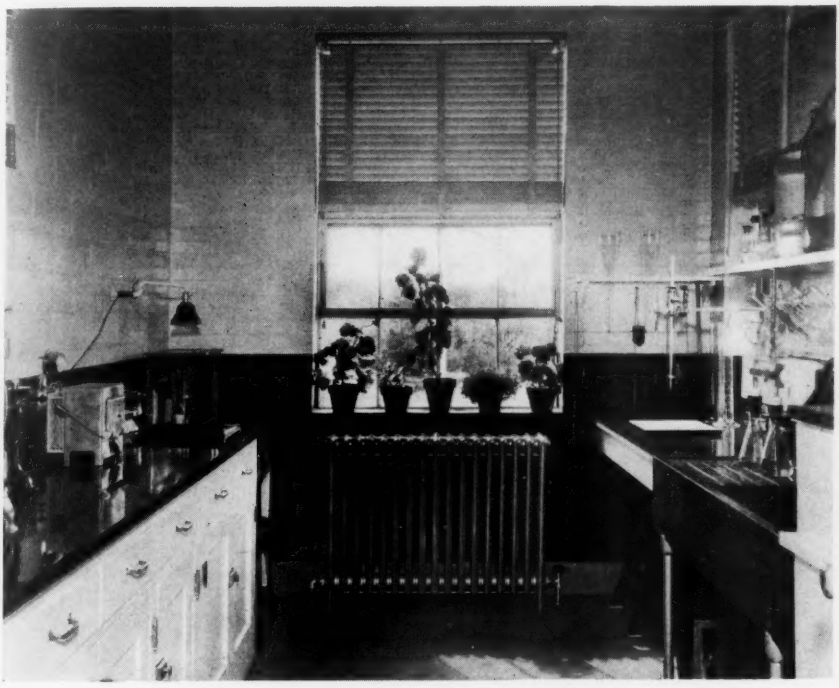

FIG. 5.—Town of Greece sewage treatment plant laboratory.

cinerator as a unit has operated perfectly, the only difficulties are caused by the ash elevator and the spiral conveyor. The ash being highly abrasive, has worn the sprockets so badly that they had to be replaced at two different times. Dust has been a source of annoyance in the operation of the incinerator, however, we have succeeded in making the casing of the elevator dust-tight, so that at present we are having less trouble.

The ash is dumped into a hopper outside of the building. Spray nozzles have been installed around the gate in the bottom of the hopper to wet the ash as it falls from the hopper to the truck. It is, however, a dusty job to empty the hopper on a windy day. Continuous attention is required when the incinerator is in operation. Rapid temperature changes on the different hearths are caused by the variation in the filter cake being fed to the furnace.

The filters were operated 818 hours or an average of 68 hours per month during 1939. Six hundred thirty-three tons of filter cake were

produced containing 25.4 per cent dry solids or a total of 159 tons. The average chemical dose was 7.1 pounds of ferric chloride and 15.2 pounds of lime per 100 pounds of dry solids.

During June, July, August and September, 1939, the filter cake was used for fill in low spots where approximately 100 loads of top soil had been removed. In the remaining eight months the incinerator was operated a total of 588 hours or an average of 73.5 hours per month. The filter cake averaged 74.0 per cent moisture and 41.8 per cent combustible material. An average of 36 gallons of fuel oil per ton of dry solids was used for the operation of the incinerator.

It is expected that when the flow to the plant increases, the sludge is fresher, and it is not necessary to add so much lime to the storage tanks, the combustible content of the filter cake will be higher and the use of auxiliary fuel will be unnecessary.

SEWERAGE IN ANCIENT AND MEDIAEVAL TIMES*

By Harold Farnsworth Gray

Sanitary and Hydraulic Engineer, Berkeley, Cal.

We frequently hear people speak of "modern sanitation" as if it were something rather recently developed, and there appears to be a prevalent idea that municipal sewerage is a very modern thing that began some time about the middle of the last century. Perhaps these ideas do something to bolster up a somewhat wobbly pride in modern civilization (concerning the inherent values of which some have their doubts), but when examined in the light of history these ideas are seen to be far from new or even recent. Indeed, in the light of history it is a matter of astonishment, if not chagrin, that man in this respect has progressed so very little, if at all, in some four thousand years.

The Mesopotamian Empires of Assyria, Babylonia, and their antecedent Sumerian and Akkadian states, marked great advances in civilization. An example is the city of Eshnunna, located about 50 miles northeast of the present Baghdad. The ruins of Eshnunna have been excavated by the Oriental Institute of the University of Chicago. These excavations exposed sewers constructed of brick, with laterals connecting to water-flushed latrines in the houses. Eshnunna is dated about 2500 B.C., or about the reign of Sargon I. But archeological researches in the past twenty or thirty years have yielded a considerable amount of of information concerning other communities either contemporary with, or antedating, the Assyrians and the Babylonians. In these other communities the art of sanitation had reached a development which might even shame some of our modern towns of similar size. At least two of them are so notable in their sanitary achievements as to be worth a brief examination. They are the Indus civilization of about 2550 B.C., and probably much earlier, and the Aegean civilization of about 3400–1200 B.C.

The Indus civilization is best known through the excavation of Mohenjo-daro, "The Mound of the Dead," which is located in Sind, about 25 miles from Larkana town, and almost due north from Hyderabad about 130 miles. A similar and larger ruin, Harappa, is located some 400 miles northeast of Mohenjo-daro, and in this general area between Mohenjo-daro and Harappa there are numerous mounds indicating other cities of this same Indus culture, and in addition there are mounds of an even earlier and distinct Amri culture.

The upper levels of Mohenjo-daro are dated about 2550 B.C. The lower levels probably go back much further, but high ground water has prevented effective excavation into these earlier cities. The mounds above the ruins average 20 to 30 feet in height (with a maximum of 70

* Presented at the Spring Meeting of the California Sewage Works Association, Avalon, Catalina Island, Monday, May 20, 1940.

feet) and cover an area of about 240 acres, but floods and erosion have probably greatly reduced the original extent of the ruins.

These Indus people had a highly developed chalcolithic (stone implements contemporary with copper or bronze) culture which was similar to and in some respects superior to the contemporary Mesopotamian and Egyptian culture. They were organized into cities, with a well developed commerce in all directions. They had wheeled vehicles for transport. They were skilled metal workers, using gold, silver, copper and lead, and tin in bronze. They made cotton into textiles. They had domesticated the dog, pig, sheep, buffalo, humped zebu, camel and elephant, but probably not the horse or cat. They had well-built and commodious houses, and baths, with drainage systems built of well-burned brick, and the common people probably enjoyed a degree of comfort unknown in other parts of the world, for in other contemporaneous civilizations the skill of the artist and builder was lavished upon the temples and palaces, but the homes of the ordinary people were apparently inadequate and ephemeral hovels.

Furthermore, the Indus civilization as known by present excavation was already old at 2500 B.C., and was not an incipient civilization, for there are several other levels, one below the other, of earlier cities, and in the lower levels the workmanship appears to be even better than in the upper-most level.

Practically every house in Mohenjo-daro had its bathroom, always placed on the street side of the building for the convenient disposal of waste water into the street drains. Where latrines have been found in the houses, they were placed on the street wall for the same reason. Ablution places were set immediately adjacent to the latrines, thus conforming to one of the most modern of sanitary maxims. Where baths and latrines were located on the upper floor, they were drained usually by vertical terra-cotta pipes with closely fitting spigot joints, set in the building wall.

These ancient terra-cotta pipes, still sound after nearly five thousand years, are the precursor of our modern vitrified clay spigot-and-socket sewer pipe, and are an excellent guarantee of the durability of this material.

Houses also had rubbish chutes built into the walls and descending from the upper floors, at the foot of which chutes there were sometimes provided bins at the street level which could be cleaned out by the scavengers. Public rubbish bins were also provided at convenient places.

The bath and kitchen waters, as well as drainage from the latrines, and the roof drainage, usually did not run into the street drains direct, but entered them via tightly brick-lined pits, with outlets to the street drains about three-quarters of the distance above the bottom. Apparently these pits were cleaned out from time to time, as were the settling basins or soakage pits located along the street drains. These pits may have been the ancient precursors of our present day septic tanks and grit chambers. In some houses the drainage water discharged into

large pottery jars placed in the street at the foot of the vertical drains in the street walls.

Each street and lane had one or two drainage channels, with brick or stone covers which could be lifted to remove obstructions in the drains. The drains were usually 18 inches to 24 inches below the street level, and varied in dimensions from 12 inches deep and 9 inches wide to about 24 inches deep and 18 inches wide. When the drain could not be covered by flat bricks, or stone slabs, the roof of the drain was corbelled.

The principal community bath was a structure of considerable size, conforming somewhat with our ideas of a swimming pool, though perhaps being used rather as a place for religious ceremonials than for either mere pleasure or for only the cleansing of the body. The structural features of the pool indicate an excellent ability in construction, considering the building materials available at that time and place. For example, waterproofing was accomplished by a membrane or coating of asphaltum between the inner and outer walls of the pool or tank.

Many of the homes had their individual wells within the buildings. These wells were usually circular in plan, though at times oval, and had copings of stone or brick at the floor level, and brick lining for a moderate depth below the surface. In a few instances the street drains ran rather too close to the wells, and it is possible that some contamination of the well occurred. But in most cases the wells were located at adequate distances from the drains.

Considered as a whole, the Mohenjo-daro ruins present a picture of a community in which both personal and community cleanliness was quite effectively practiced, and the water supply reasonably safeguarded from contamination as a rule.

But lest it be assumed that the prehistoric Indus civilization was a rare and unusual thing, let us examine the nearly contemporaneous and very remarkable civilization which flourished around the Aegean Sea about 3000–1000 B.C. It is shown in its highest development in the ruins of the Palace of Minos near Knossus on the Island of Crete.

The Minoans were builders of splendid palaces of stone; they constructed paved roads and viaducts; they had developed a high degree of art in frescoes, in statuary and bas-reliefs, in decorated pottery, and in medallions. Their gold and silver work was of a high order, they were skilled workers in copper and bronze, and they made exceptionally fine textiles. Some of their statuettes, for example the statuette of the snake goddess, are almost startlingly modern in conception and execution.

They had developed a considerable knowledge of hydraulics. They built fountains, which shows that they knew how to carry water in pipes under pressure. Tapered terra-cotta pipes have been found, with spigots, collars and stop ridges, among the earliest elements of the palace. Water for drinking was apparently obtained also in part from wells, many of which were lined with hard terra-cotta liners, each section being one-third of the periphery, and having a slight socket at the top of each ring to fit the bottom of the next upper ring. Their bath

tubs were remarkably similar to our modern tubs, and perhaps more artistically decorated.

Particularly in the Middle Minoan Period, dated about 1900–1700 B.C., elaborate systems of well-built stone drains were constructed, which carried sewage, roof water and general drainage. The main drain transported these wastes a considerable distance beyond the palace, but we do not know the method of their final disposal.

Each quarter or section of the palace had its own subsidiary drainage system connected to the main drain. These systems had vertical shafts of ample size which acted both as roof drains and as ventilation ducts, the latter in much the same manner as do the soil stacks in our modern houses. The frequent and torrential rains in Crete would result in excellent flushing of the entire drainage system.

Such sanitary arrangements were not particular to the palace at Knossus, but seem to have been an essential part of all Cretan building. A. Mosso, in describing the ruins of the villa of Hagia Triada, makes the following statement:

> One day, after a heavy downpour of rain, I was interested to find that all the drains acted perfectly, and I saw the water flow from sewers through which a man could walk upright. I doubt if there is any other instance of a drainage system acting after 4,000 years.

Perhaps we also may be permitted to doubt whether *our* modern sewerage systems will still be functioning after even one thousand years.

Latrines were provided within the palace, directly connected to vertical chutes or to horizontal drains. Apparently these latrines were flushed after use by emptying a large jar of water into the latrine. The latrine seat was the edge of a wood plank set vertically into recessed slots in the side walls, with the rear wall as a back rest, which was effective but perhaps not quite so comfortable as our modern split-front seats of plastic.

Rubbish was apparently placed in a number of circular walled pits, about 5 meters in diameter, which were probably cleaned out from time to time as necessary.

All in all, the archeological researches on this site yield a picture of a people who had progressed far along the path of comfortable and hygienic living, with a considerable degree of beauty and luxury in their surroundings. And this had been accomplished some four thousand years ago.

All are familiar with the high degree of sanitation achieved by the Romans, but certain rather commonly held errors need correction. For example, the so-called sewers of Rome, of which the Cloaca maxima is the best known, were primarily conduits for the removal of surface drainage (rain water) and underground water. They were not designed as sewers as we understand them today, had few house connections, and were not expected to receive excrement directly. But apparently in ancient Rome excrement and other wastes were thrown into the streets, and thence flushed into the drains in the process of street

cleaning. One of the complaints of Frontinus, the Roman water commissioner of about 100 A.D., was that so much water was feloniously diverted from the aqueducts, for agricultural irrigation outside of Rome, that there was at times insufficient water for cleaning the streets.

Mediaeval and even modern Europeans, so far as sanitation was concerned, were certainly not above the savage level, and even fell below it. In Berlin, the refuse heaps piled up in front of St. Peter's Church until in 1671 a law required every peasant who came to town to remove a load of filth when he returned home.

In 1183, when the Emperor of the Holy Roman Empire held a Diet in the palace of Erfurt, the floor of the main hall broke, precipitating the lords and knights into the cesspool below, where many perished, the Emperor himself barely escaping death.

In Denmark, the cleaning of the latrines was the job of the hangman, who probably did the job very poorly indeed, for in Helsingor in 1583 a Hollander residing there outraged the community by personally cleaning out his latrine after repeated efforts had failed to induce the town officials to have the job done.

Paris in the Middle Ages was the metropolis of Europe and at least superficially the focus of refinement in living. But the streets were foul with filth. Montaigne complained that he found it difficult to rent lodgings where the reek from the streets did not assault his nose. Parisians freely emptied chamber-pots from their windows, only the nimble and the lucky escaped being drenched. The poorer classes defecated indiscriminately wherever most convenient. In 1531 a law required landlords to provide a latrine for every house, but it does not appear to have been well enforced. Toward the time of the French Revolution privies were numerous in Paris, but apparently they were so filthy that even the least fastidious preferred other places. A favorite locality was the terrace of the Tuileries, which eventually became so fouled that the superintendent of the royal grounds installed a latrine, charging an admission fee of two sous.

Enraged at the high price, the public removed their excretory affections to the Royal Palace grounds, forcing the Duc d'Orleans to construct a dozen privies, which fortunately were better patronized. But the Louvre was a mess. People defecated without restraint or attempt at secrecy in the courtyards, on the stairs and balconies, and behind doors, without hindrance by the palace attendants. And if the commonalty were guilty of such gross violations of sanitation and decency, they had excellent examples in high places. On August 8, 1606, an order was given prohibiting any resident of the palace of Saint Germain from committing a nuisance therein. That same day the King's son urinated against the wall of his room.

The disposal of excrement in mediaeval England presented problems which the Englishman of that day tried to solve in various ways, most of them much inferior to the methods developed nearly three thousand years prior in Crete. Little is known of the methods used by the agricultural population; it was probably quite casual. The wealthy

lords built several types for their castles. Where there was running water in the moat, garderobes or latrines were sometimes corbelled out over the moat from the face of the exterior wall, so that the dejecta had a fairly clear drop into the moat. In winter this arrangement was probably cold and drafty, and no doubt the exterior wall was rather well plastered with excrement. In other instances chutes were built into walls, or in separate turrets, and water diverted through the base of the chute. However, this was apt to result in bad odors due to fouling of the sides of the chutes.

Where running water was not available for carrying away the excrement falling into it, pits or cesspools were constructed, frequently of masonry, for storing the excrement received from the floors above via various types of chutes. Chutes were frequently built in the thick walls of chimneys, for warmth, but this undoubtedly added to the odor problem. In other cases the cesspool must have been below the floor, for according to the Coroner's Roll of 1326, Richard the Raker having entered and seated himself, the rotten planks of the floor gave way, and Richard perished most odorously by drowning in the contents of the pit.

In a few cases pipes or channels were built to remove the overflow of the pits, as at Westminster Palace about 1260, but by 1307 this conduit became so blocked with filth that it had to be cleaned out and repaired. However, some of our modern sewers have not lasted forty-seven years, wherefore let us not be censorious.

In mediaeval London the problem was made more difficult because of overcrowding. Public latrines, with running water for the clearance of the excrement, were known in London prior to 1290. Tenements were usually inadequately provided with latrines; for example, in 1579, in Tower Street in the Parish of All Hallows, there were three privies for eighty-five people. Doubtless even in normal times a considerable amount of excrement was simply thrown into the streets and lanes, because of the inadequate and malodorous privies; in abnormal times this condition was aggravated, for in the plague year of 1349 the King ordered city authorities to remove the filth accumulated in the streets and most foully polluting the air of the city, although the city was one-third depleted of its population by the plague.

If the Mediaeval European was a failure in sanitation, his bad example did little to improve the modern European until the very recent present, and then but partially.

In London, the discharge of any water except kitchen slops into the drains was prohibited by law until 1815, and this regulation persisted in Paris until 1880. In London the report of the Health of Towns Commission in 1844 revealed such astonishing amounts of decomposing excrement and organic matter throughout the English cities that the report aroused a strong movement to improve conditions which had long been intolerable. By 1847 it had been made obligatory by law to discharge excrement into the drains, and the cesspits, pail privies and kitchen middens were gradually abolished. But if the Englishmen's long struggle with excrement disposal made rather slow progress in

achieving a satisfactory solution of the problem, it proved highly successful in the production of laughable tales concerning their ineptitudes in this respect, including some hilarious incidents in their novels, for example the inn scene in "Roderick Random." Moliere and other French writers used similar materials, though with greater deftness. Indeed, it would be most surprising if such an ever-present factor in daily life failed to be reflected in the literature of the time.

The Englishmen of the last century finally did succeed in divorcing themselves from immediate juxtaposition with their own excrement and the stench thereof, thereby at long last catching up in part with the Minoans of nearly 4000 years previously, but they for a while merely exchanged one problem for another. As early as 1842 the Poor Law Commissioners advised against the discharge of sewage direct into streams which were used for water supply. London, of course, had simply removed its excrement from accumulation of reeking filth in and about the houses, and transferred the entire mess into the Thames River, within the city limits. Nothing was done about it until 1855, when at the end of a disastrous epidemic of Asiatic cholera (that great blessing of man because it has literally terrified him out of his sanitary apathy and into sanitary improvements), the Nuisance Removal Act was passed, prohibiting gross river pollution. But, in spite of the cholera, for quite a while the interference of gross pollution with the industrial and agricultural uses of water was given more attention than the menace to health. In passing it might be mentioned that London was still to suffer two more great epidemics of cholera, in 1866 and again in 1872, showing how slow human progress was even in the face of the most urgent compulsion.

London, of course, reaped the reward of its bungling attempts to clean up the city by dumping sewage into the river. The years of 1858–59 were the years of the great stink in London. This was vividly described by Dr. William Budd as follows:

> For the first time in the history of man, the sewage of nearly three millions of people had been brought to seethe and ferment under a burning sun, in one vast open cloaca lying in their midst. The result we all know. Stench so foul, we may well believe, had never before ascended to pollute this lower air. Never before, at least, had a stink risen to the height of an historic event. Even ancient fable failed to furnish figures adequate to convey a conception of its thrice Augean foulness. For many weeks, the atmosphere of Parliamentary Committee-rooms was only rendered barely tolerable by the suspension before every window, of blinds saturated with chloride of lime, and by the lavish use of this and other disinfectants. More than once, in spite of similar precautions, the law-courts were suddenly broken up by an insupportable invasion of the noxious vapor. The river steamers lost their accustomed traffic, and travellers, pressed for time, often made a circuit of many miles rather than cross one of the city bridges.
>
> For months together, the topic almost monopolized the public prints. Day after day, week after week, the "*Times*" teemed with letters, filled with complaint, prophetic of calamity, or suggesting remedies. Here and there, a more than commonly passionate appeal showed how intensely the evil was felt by those who were condemned to dwell on the Stygian banks. At home and abroad, the state of the chief river was felt to be a national reproach. "India is in revolt, and the Thames stinks," were the two great facts coupled together by a distinguished foreign writer, to mark the climax of a national humiliation.

And this nearly four thousand years after the prehistoric Cretans! How we did progress!

Our English cousins were not slower nor were they less intelligent than the inhabitants of other European countries. Similar conditions could be described "ad nauseum" in various European cities, and also in some of our own (Bubbly Creek in Chicago), but they were unfortunately not described in Budd's pungent prose. And in passing it may be mentioned that in 1940 we ourselves are performing a very fair job in the creation and maintenance of monumental stinks that would do credit to the most barbarous community. For reasons of at least a moderate delicacy, I refrain from naming names.

Urban man today still unnecessarily pollutes streams, bathing beaches, bays and estuaries, without benefit of the excuse of ignorance which was available to his ancestors.

Sewage works associations, engineering societies and the public health associations are doing good work in enlarging the technical knowledge needed to solve our sanitary problems, but whether they can do much to jolt the sanitary conscience of the average man into really adequate sanitary action still seems to be dubious. We appear at present to be possessed of more technical knowledge than we are permitted to apply, due to the conflict between the immediate dollar of sanitation expenditure versus (to the average man) rather intangible future comforts and benefits.

If our progress today is so much less than what we know is possible, let us not be disheartened. Even though in four thousand years we have accomplished relatively little in sanitation, remember that after all that is but a small sector of time in man's history. He has existed in substantially his present type for at least 150,000 years, during which time he has not abolished or appreciably diminished war, or famine, or pestilence, nor murder, avarice, greed, intolerance, nor economic disasters, nor does it appear to be even probable that he will ever do so, and probably our great-grandchildren's remote descendants will still be struggling with the problem of disposing of their excrement.

Stream Pollution

POLLUTION CONTROL WORK OF THE CALIFORNIA STATE DIVISION OF FISH AND GAME*

By Paul A. Shaw

California State Division of Fish and Game

Papers by Howard Vernon [1] and Colonel Kelton,[2] presented at the last meeting of the California Sewage Works Association, together with Mr. Rawn's discussion of the latter,[3] served to indicate California's growing interest in the problem of pollution control. Since both speakers mentioned pollution activities of the Division of Fish and Game, it may be of interest to extend the series; it is therefore the purpose of this paper to describe more fully the work of our Pollution Detail. First, however, it would appear desirable to discuss the legal status of pollution control in California in order to have a clearer picture of the situation.

Legal Status in California

In California, since no interstate compacts exist, we are limited to three of the four control methods pointed out by the National Resources Committee [4] and further discussed at the last meeting of this Association. These are:

1. Enforcement of Federal Laws
2. Enforcement of State Laws
3. Injunction or private damage suits.

Federal Law.—Under Federal Law, where navigable waters may be affected, action can be taken to prohibit the discharge of oil from vessels and to prohibit the discharge of refuse from vessels or shore plants, exclusive of that flowing from streets and sewers in a liquid form. While it has been indicated that Federal jurisdiction is very limited, this support has been most valuable to our Pollution Detail in reducing harbor and coastal pollution. The co-operative enforcement work with the U. S. Engineers, U. S. Customs, and U. S. Coast Guard, described in Colonel Kelton's paper and by Shaw and Towers in a previous illustrated bulletin [5] was initiated largely through the efforts of Warden C. L. Towers, who was assigned to our pollution work in 1935. Since that time an active Federal program on pollution enforcement has spread to the east coast and other ports following the transfer of officers who became familiar with the work of our Pollution Detail in California.

In addition to the Federal jurisdiction just described, certain Federal restrictions on hydraulic mining debris in the Sacramento River

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watershed are in force. In this connection, due to the rapid growth of gold dredging operations, many of which have a daily capacity of several thousand tons, it is unfortunate that regulations of the California Debris Commission have not been modified to include the control of silt from this source.

State Law.—In this state the Public Health Act and Section 481 of the Fish and Game Code are the principal statutes providing means of pollution control. The Public Health Act restricts the pollution control work of the State Department of Public Health and local health districts to those conditions which are shown to be a nuisance or menace to health. While this Act embodies an elaborate permit system and provides for an adequate technical staff, it is weak in enforcement features and consequently raw sewage is still discharged from many municipalities that have knowingly escaped restriction by failure to request a permit.

The Fish and Game Act, except for certain named substances, restricts pollution control to those conditions deleterious to fish, plant life, or bird life. This section is strong to the extent that proof of damage is not essential for items such as petroleum, acid, sawdust, and certain types of factory refuse that are specifically named in the section.

While it is logical that health laws should control pollution, from the standpoint of health and fish and game laws, only from the angle of aquatic life, the unfortunate situation is created that neither agency can act on justified complaints when the damage is to agricultural, industrial, or recreational uses. In instances of this type, injunction proceedings or damage suits constitute the only remaining recourse.

Notwithstanding the limited scope of our fish and game section, we feel that much has been accomplished in the past few years by the Pollution Detail towards eliminating severe sources of pollution. Many conditions not fully covered by law have been corrected through cooperative work, and remedies effected for conservation of aquatic life have been beneficial from the standpoint of other water uses.

Control of Waste Disposal

Petroleum Products.—Losses of oil in harbor and coastal areas from ships and vessels, occurring during the loading of oil at terminals, from broken lines, overflow of tanks, or through the pumping of oily bilge, have constituted a severe source of pollution in the past. Active enforcement work of the Detail in co-operation with Federal authorities has reduced this source to a minimum, but constant patrol efforts must be maintained to prevent careless practices being renewed.

At shore plants such as oil refineries, and wells, manufacturing establishments, railroad round houses, etc.; insistence on adequate separating and skimming devices, properly constructed sumps and clean-ups in case of accidental spills has served to reduce former sources of oil pollution. The improvement has been particularly marked at the round-houses, car washing and oil loading stations of the railroad companies.

In certain oil fields, in addition to separation of oil from the waste water, studies are now under way to eliminate sulfide compounds and suspended solids which have created serious degrees of pollution in coastal areas. In one southern California field where research has been in progress for over two years, following insistence by our Detail, an appropriation of approximately $120,000 is being provided for installation of a complete treatment plant.

Mining.—Due to the increased price of gold, there has been a large expansion of mining activities in the past few years. This applies to all types of mining.

The spent ore from milling operations is extremely deleterious to fish life and this material also covers stream beds, preventing the growth of food organisms and development of spawn.

Through the work of our Pollution Detail, many mills have installed impounding areas where the tailings are stacked and the settled effluent is then discharged to State waters. In certain areas impounding is still a seasonal matter, the tailings being permitted to wash out during storm periods. Definite progress is being made, however, looking toward permanent impounding of all mill tailings.

As previously mentioned, gold dredging operations constitute a severe source of pollution that is not controlled by the California Debris Commission. At the present time about 165 such operations are in progress in the northern part of the State. Proof of damage to fish life is difficult with silt of this type and damage to other interests is probably greater than that to aquatic life. Despite this fact, improvements have been effected in many instances through co-operative efforts. In general, for dredging operations, we request adequate settling ponds and by-passing of the normal stream flow. In this connection our laboratory found that proper dosages of lime and alum would flocculate the collodial clay particles satisfactorily and a number of operators have utilized this procedure for clarification of dredge tailings. Recommendations for chemical treatment of dredge tailings were published in *Mining and Industrial News* for December 15, 1938.

Hydraulic mining is being renewed following construction of debris dams by the Federal Government. These dams are designed to prevent debris reaching the valley areas where it would constitute a menace to navigation. It is apparent that the recreational public is not sympathetic to the renewal of hydraulic operations since tailings pollute streams for many miles between the mining operations and the debris dam. In addition, the dams only settle out the heavier material and muddy effluents have caused many complaints. In one instance an injunction was recently secured against a hydraulic operation for pollution of a municipal supply below the debris dam.

With the renewal of mining, it has been necessary to pump out many old tunnel shafts. Such waters may be high in acid and metals deleterious to fish life. The pumping of one tunnel resulted in the death of fish sixty miles down stream. Immediate action was taken to prevent further drainage; the tunnel water was impounded and has now evapo-

rated to a large extent making the mineral content available for recovery.

A severe condition of tunnel drainage exists in the area above the Shasta Dam, now under construction. While the drainage from these abandoned copper mines may not seriously affect the Sacramento River, it is felt that damage will occur following completion of the reservoir, since narrow arms of the reservoir will fill with water of sufficient acid and copper content to prevent the development of any aquatic life. A complete study of this matter is in progress and a Federal project may be requested to seal the tunnels, thus preventing access of air and further oxidation and solution of the ore.

Food and Beverage Wastes.—At a previous meeting of this Association, the writer presented a paper [6] covering studies on winery wastes and indicated that disposal of still slops to the Mokelumne River had been prohibited. The following year one winery developed a treatment method using lime and a trickling filter which appeared to give excellent purification.

Unfortunately the 1938 winery season occurred during an election period and due to pressure brought by certain interests, our enforcement program was dropped and further research work by the industry was discontinued. In 1939, due to low stream flows, the situation in the Mokelumne River became serious soon after the winery season opened and salmon, bass, perch, and other species of fish were killed for many miles below the winery outlets. Immediate action was then taken to enforce the law and two weeks later the wastes were being disposed of in sumps or on land. The river cleared rapidly and the remainder of the salmon run continued up stream to spawning grounds. No further disposal of untreated waste to the river will be permitted and we understand that one winery anticipates installation of a complete treatment plant along the lines previously worked out. It is indeed unfortunate that conditions must at times reach such a critical state before remedial action can be enforced.

In the San Joaquin delta, where celery packing for the eastern market is concentrated, a waste collecting plant costing $30,000 to $50,000 was completed last year, following a two year program to have this condition corrected. Waste from this source, totaling 30–35 per cent of the celery received from the field, was formerly discharged to the river. The installation includes a 1700 foot flume into which water is pumped to float the waste from twelve concerns to a central point. It is then picked up by a belt conveyor discharging to a large bin under which trucks are driven for loading. Floating by means of a flume eliminated the necessity of installing individual conveyors for each packing company in the shed. It is our understanding that the packers now receive 50 cents a ton for this waste and that it is resold as cattle feed by the trucking concern for $2.50 per ton.

A severe degree of pollution from fruit and vegetable canning wastes has existed in the valley and bay area for many years, the principal products being asparagus, peaches, and tomatoes. Solid wastes have

been discharged direct to State waters or passed through grinding machines and discharged to State waters through city sewers. Instructions were issued to individual canners and the Canners League of California in 1938 to discontinue this practice; the restrictions covering only waste that could be removed as garbage like material. A number of small canneries complied with these regulations in 1939 but the larger concerns, while appearing co-operative, failed to take definite remedial steps. For 1940, through an agreement with the Canners League, all plants are required to dispose of one-third of the waste by other means than discharge to State waters. By the following year, pollution from this type of waste should be practically eliminated. Additional surveys will then be undertaken to determine whether the remaining soluble components in cannery wastes cause a sufficient oxygen depletion to necessitate further restrictions.

Fish canning and reduction in the San Pedro, Monterey and San Francisco areas has been a source of pollution for many years. Through the efforts of our Pollution Detail many firms have now installed screens and settling tanks which remove a large portion of the suspended solids. These are added to meal production and have thus added to the revenue. The bilge water from purse-seine boats, which contains about two per cent suspended solids, is now pumped into the plants at San Pedro and Monterey and passes through the screens and settling tanks provided. A similar method will be employed in the San Francisco area this coming season.

The principal pollution load from the fishing industry is the waste, known as "stick water," remaining after removal of fish oil and meal in the reduction process. This waste contains about six per cent organic matter, high in protein and vitamin content, and should be profitable if an economical recovery method is developed. At least three concerns have studied this problem and our own laboratory has shown that pollution from this source can be reduced about 70 per cent through a coagulation process utilizing sulfuric acid. In view of this work instructions have recently been issued that equipment must be provided at the beginning of the August season to materially reduce pollution from this source. Analyses of stick-water have shown that pollution from this source on peak fishing days in the San Francisco Bay area is equivalent to the raw sewage from a population of 5,000,000.

Sugar refineries have been another source of waste, causing damage to fish life in several California areas. However, we have generally secured good co-operation from plant operators, and disposal on land or by discharge following settling and lime removal, where adequate dilution is available, has generally proven satisfactory. One plant where adjacent land owners have objected to land disposal is now installing a treatment unit. Another plant will impound concentrated wastes this coming season, the remainder being discharged direct to the ocean.

Miscellaneous Waste Products.—At various saw mills, chemical plants and manufacturing concerns throughout the State many im-

provements have been effected where wastes formerly polluted our streams. These will not be described, however, since the foregoing material is sufficient to indicate the work being done by our Detail.

Personnel and Operation of the Pollution Detail

Before concluding, it may be of interest to indicate, briefly, the organization and method of operation of our Pollution Detail.

The personnel is composed of technically trained men working under the budget of the Bureau of Fish Conservation and Patrol Officers assigned to the unit from the Bureau of Patrol, the total number varying from 8–10 men. The co-operation of all other field men of the Division of Fish and Game is solicited, to render prompt notice on any pollution violation or condition requiring attention, but instructions have been issued not to file cases or recommend remedial measures since the work is specialized and must be handled uniformly.

We believe that our success to date is the result of proper correlation of technical, co-operative and enforcement work, the desire being to correct conditions rather than to emphasize court fines. Notwithstanding this policy 210 cases with fines totaling $35,265.00 have been prosecuted under the efficient supervision of Mr. Towers during the past five years. No case is brought into court without a full written report, together with samples, photographs, and analyses if needed. When the pollutant is not fully covered by law, stream surveys and complete technical data are secured, in most instances the condition then being corrected by request.

Conclusion

From the work that has been done we know that aquatic and recreational conditions in many areas have improved to a marked degree, but the work is far from complete. Years will be required to eliminate many polluted areas, and even then constant effort will be required to maintain and protect State waters from potential sources of pollution.

In conclusion, the writer wishes to express the opinion that a central state agency or advisory board for pollution control may later be advisable. This belief is based on the trend of legislation elsewhere, on the limited scope of both the Health Law and our own law, and on the right of the people to refer complaints to an agency with statute authority to act from all standpoints of water use, including agricultural, industrial and recreational value. Such a set-up would eliminate the just criticism of discrimination when we expect industry to correct conditions while a line carrying raw sewage is permitted nearby. Further, industries, municipalities, consulting engineers and equipment firms would then be assured that the requirements of one agency are final and that procedures recommended by one agency are not going to be frowned on by another.

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THE ALLOCATION OF RESPONSIBILITY FOR BACTERIAL POLLUTION IN A STREAM *

By L. F. Oeming

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In studies involving bacterial pollution of streams, cases arise in which the responsibility for conditions is divided between several population groups of various sizes and at various distances upstream from a specified zone. Evaluation of the effects of sewage discharges from each group or municipality may be required where improved bacteriological quality of the water is desired for the protection of a water supply or recreational area. The need for such an allocation arose recently in connection with action by the Michigan Stream Control Commission to obtain abatement of pollution in the St. Joseph River below the City of Niles.

From its source in Michigan, the river passes through Indiana, and then returns into Michigan where it discharges into Lake Michigan at Benton Harbor and St. Joseph. In passing through Indiana it receives the untreated sewage from the municipalities of Elkhart, Mishawaka and South Bend. After crossing the state line into Michigan it receives sewage from Niles, Buchanan and Berrien Springs. Both Buchanan and Berrien Springs now have treatment plants, but the studies were made prior to their operation so they are included as raw sewage sources.

The river zone most seriously affected by these discharges lies between Buchanan and Berrien Springs. In this zone the river is highly developed for recreational use, both public and private. Five permanent camps are maintained for use of Boy Scouts, underprivileged children, and others. Sewage pollution has resulted in injury to fish life, depreciation of property values, and presents a health hazard to the occupants of the camps where bathing is a part of the recreational program.

On the basis of actual sewered population, the responsibility for these injuries would be proportioned about as follows:

City	Population	Per Cent Responsibility
Mishawaka	30,000	19.3
South Bend and suburbs	110,000	70.8
Niles	11,300	7.3
Buchanan	3,900	2.6

Eliminating the City of Elkhart, since the effects of its pollution have almost disappeared immediately above South Bend, leaves the total actual sewered population tributary to this zone of 155,200.

* Presented at the Spring Meeting of the Michigan Sewage Works Association, Lansing, May 9, 1940.

However, the true effects of the pollution sources are not properly represented by these figures since allowance has not been made for the reduction of bacteria in the stream from the several sources by forces of natural purification. Methods of evaluating the effect of these forces have been developed by Streeter, Hoskins, and others of the U. S. Public Health Service, based on surveys of the Ohio River below Cincinnati in 1914–1916. From these surveys it was found that the introduction of sewage into a stream effects an immediate increase in bacterial content proportional directly to the volume and concentration of the sewage, and inversely to the volume of stream water.

$$\frac{Q_r D_r + Q_s D_s}{Q_r + Q_s} = \text{Pollution density except as modified by imperfect mixture}$$

Beyond the point of maximum density, the bacteria tend to diminish along a fairly well-defined time—function curve due to the forces of natural purification, the rate of decrease being modified by temperature. Under summer conditions, the equation of the curve is—

$$Y = 99.51(10^{-.0195\,x}) + 0.49(10^{-.00242\,x})$$

in which Y equals the bacteria remaining after the time of flow x in hours below the point of maximum concentration, Y being expressed in per cent of the maximum at the point of pollution. By this formula the *B. Coli* remaining after 20 hours flow time is 41 per cent of this initial concentration, at 40 hours, 17 per cent, and at 100 hours 1.4 per cent.

Stream surveys by the Commission in 1935 were made to determine the existing bacteriological conditions at various points in the stream. From these surveys the point of maximum concentration of coliform organisms due to Mishawaka—South Bend sewage was established as being at the Angella Street bridge near the north limits of South Bend. The average coli index at this station was found to be 56,400.

Beginning at this point and substituting the time of flow to downstream sampling stations in the formula, theoretical values of the *Coli* index were obtained and were compared with the actual index as found by sampling at these stations. The close agreement between the true value and the theoretical or computed value permitted the conclusion that the formula represented the rate of natural purification in this stream. In other words, the actual observations fit or coincided with the definitely formulated curve within practical limits.

From the Ohio River studies it was shown that the increase in sewage organisms in a stream bears a definite relationship to the population contributing the sewage. It was, therefore, concluded that the computed percentages from which the numbers of sewage bacteria expected to survive after various time of flow intervals were obtained could also be applied to the actual numbers in the sewered population group to obtain the equivalent population at any point. By thus reducing each sewered population group in accordance with the mean times of flow above the point under consideration, and by adding the resulting equivalents, a figure is obtained representing the population which if it dis-

charged its sewage immediately above the point would produce the same pollution effect as the actual population distributed at various distances upstream.

In the zone from Buchanan to Berrien Springs the population equivalents obtained by use of the formula are as follows:

	Population	Per Cent Responsibility
Mishawaka	2070	11.1
South Bend and suburbs	9994	54.3
Niles	3970	21.8
Buchanan	2325	12.8

While it is appreciated that there are limitations to this method of evaluation due to wide variations which occur in the determinations of coliform organisms in river waters, it is believed that if a sufficient number of analyses are made, the possible sources of error will compensate and the data will lend itself to this evaluation of quantitative relationships. In any event, it represents a rational approach to the solution of problems of this nature.

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Industrial Wastes

STUDIES ON THE TREATMENT OF SEWAGE AND TEXTILE WASTES BY RECIRCULATING FILTRATION

I. DOMESTIC SEWAGE ON BATCH BASIS *

By Ralph Porges, Henry J. Miles and Herman G. Baity

Special Investigator and Former Special Investigator, Textile Foundation, Washington, D. C., and Professor of Sanitary Engineering, University of North Carolina

Recent developments in the recirculation of filter effluents through biological filters have demonstrated the possibility of adapting such a procedure to the treatment of strong wastes.[2, 7, 9] Previous experiments [8] have suggested the possibility of treating textile wastes by recirculating filtration; however, the lack of sufficient information indicated the desirability of making a study of this type of treatment in order to gather basic fundamental data. A series of experiments on sewage treatment by recirculating filtration on a batch basis was inaugurated. This paper reports the results of these experiments. Additional contributions which will describe the treatment of sewage and/or textile wastes, both on batch and continuous operation, are in preparation.

Description of the Experimental Plant

The filter plant used in these experiments consists of various units which are mounted on an open platform as shown in Figs. 1, 1*a*, 1*b*. The filter consists of two sheet-iron cylinders each with a diameter of 4 ft. 7 in. and a length of 4 ft. 6 in., standing on end, one on top of the other. The filter proper is contained in the upper cylinder and consists of 2 to 3 in. broken stone to a depth of 4 feet. This upper cylinder rests upon a wooden grill contained in a shallow metal pan 5 ft. 7 in. in diameter. The wooden grill serves as a means for natural ventilation and as support for the broken stone. The metal pan gathers the effluent for discharge. The lower cylinder is merely a base for the filter proper. On top of the stone bed within the upper cylinder rests a shallow perforated distributor pan, slightly smaller in diameter than the filter. A vertical sheet-iron partition divides the distribution pan, rock filter, and effluent pan into two sections that may be operated as two distinct filters. Each section of the effluent pan is connected to its own 210 gallon detention tank. The detention tanks have a sump in the middle at a slightly sloping bottom through which the waste is withdrawn to be applied to the filters. No appreciable amount of settling takes place in

* This research project was carried out under joint sponsorship of the University of North Carolina and the Textile Foundation.

the detention tank. The recirculation pumps are 1½ in. centrifugals with their suction lines attached to the detention tanks, while the pressure line of 1½ in. iron pipe leads up to the top of the filter where the flow is divided by a "T" and distributed as two continuous streams to

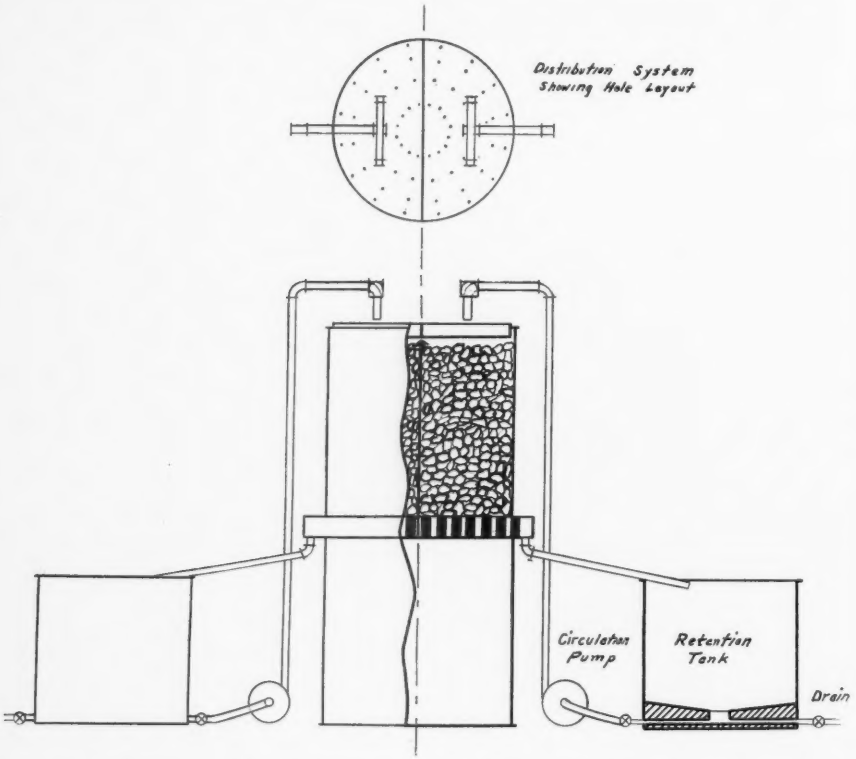


FIG. 1.—Diagrammatic sketch showing plant layout for experimental studies on recirculating filtration.

each side of the distributor pan (see Figs. 1, 1*a*, 1*b*). The rates of flow are measured by orifice meters and may be varied as desired over wide ranges by means of valves.

This 4 ft. coarse-rock filter was operated on the recirculating principle with continuous dosage at both high and low rates. There has been incorporated into this filter various factors designed to increase the efficiency of the trickling filter. According to Halvorson, Savage and Piret [1] filters dosed continuously should function efficiently at high rates. Likewise Levine, Nelson and Gorsline [2] state, "In general, it may be concluded that for a given rate of application on a coarse-grained filter, the shorter cycles produced effluents, which were more highly purified, more uniform in composition, and more constant in run-off. The more uniform the rate of runoff the more nearly the maximum

efficiency of the filter is approached for the load it is receiving." These observations indicate that continuous loading should give optimum conditions.

The size of aggregate may influence the rate of purification. Halvorson [14] and Jenks [3] obtained good results at high dosages with coarse material from 1.5 to 3 inches. Imhoff [13] claims that fine material is not essential and is not to be recommended, since stoppages may occur.

FIG. 1*a*.—View of filter and detention tank showing details of the filter base and recirculating system.

Studies made by Jenks [3] using recirculation showed the feasibility of utilizing filter depths of 3 ft. or less in order to decrease pumping costs. The results obtained by Levine, Nelson and Gorsline [2] show in most cases, that the 4 ft. depth is sufficient when the reduction in oxygen consumed is used as a basis of measurement.

Bottom ventilation is not only essential but indispensable for adequate purification according to Levine and Gorsline [4] who investigated

the problem of aeration and ventilation. Molhman's [5] results on high-rate filtration showed that artificial aeration had no advantage. Further reports on this work by Herrick [6] showed similar results.

FIG. 1*b*.—View of filter showing distribution system.

PROCEDURE

All operations were conducted on a batch basis. The sewage was obtained from the outfall sewer on the north side of the City of Greensboro and consisted primarily of domestic waste. The sewage was pumped to a mixing tank and then distributed to the detention tanks of the filter units. The sewage was recirculated through the filter at designated rates of flow. Samples for analyses were taken from the effluent line of the filter prior to discharging to the detention tank. The periods between sampling usually corresponded to the recirculation interval or multiples thereof. In order to standardize the analytical procedure, all effluent samples were caught in ⅔ gallon bottles and settled for ½ hour. All analyses were made according to the procedures found in "Standard Methods of Water and Sewage Analysis" of the American Public Health Association (1936).

In a study of the recirculating filtration process a consideration of the following controllable factors is necessary:

1. Rate of filtration.
2. Initial load as measured by B.O.D.
3. Number of recirculations.
4. Total time of treatment.
5. Contact time in the filter.

In these studies each factor was varied while the others were kept as constant as possible. This was facilitated by utilizing the two filters in parallel. For ease of interpretation, the various runs have been grouped according to the variable factor.

Results

Rates of Filtration.—150 gallon volumes of sewage were recirculated through the filters at rates of 8, 16, 24, 40, and 160 m.g.a.d. At various

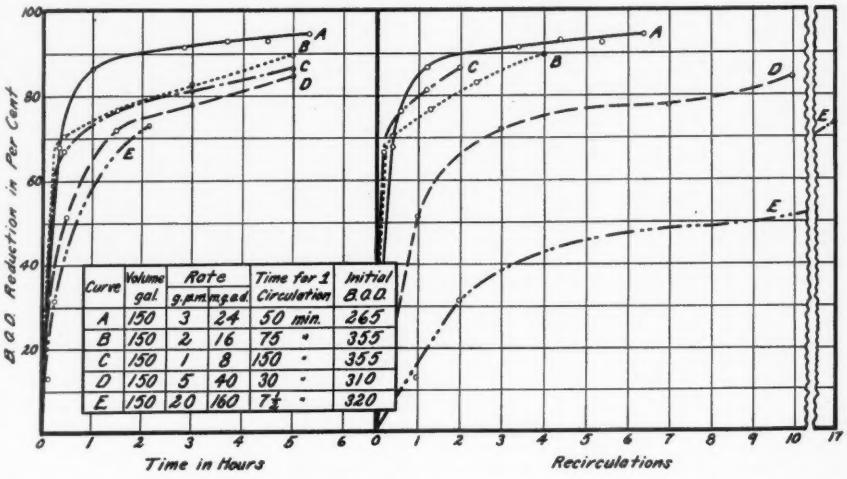

B.O.D. Reduction in Per Cent
Time in Hours
Recirculations
A
B
C
D
E
Curve | Volume gal. | Rate g.p.m. | Rate m.g.a.d. | Time for 1 Circulation | Initial B.O.D.
A | 150 | 3 | 24 | 50 min. | 265
B | 150 | 2 | 16 | 75 " | 355
C | 150 | 1 | 8 | 150 " | 355
D | 150 | 5 | 40 | 30 " | 310
E | 150 | 20 | 160 | 7½ " | 320

Fig. 2.—Per cent reduction in B.O.D. obtained by recirculating 150 gallons of sewage at various rates.

intervals the B.O.D. of the liquor was determined and the results obtained are plotted as Fig. 2. The data show that best results, as measured by per cent reduction in B.O.D., were obtained with a filtration rate of 24 m.g.a.d. under the stated operating conditions. Poorer results were obtained when filtration rates were raised or lowered; however, a survey of dissolved oxygen data given in Table I indicates that the lack

Table I.—*Dissolved Oxygen in the Detention Tank During Runs A to E*

No.	Dissolved Oxygen in the Detention Tank							
	Total Time of Treatment in Hours							
	0	½	1	1½	2	3	4	5
A	0.9	6.2	6.4		6.9	6.3	6.5	6.5
B	0.0	0.0	0.9	1.4	1.7	2.9	3.6	4.1
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
D	D.O. Present—No quantitative results							
E	0.0	3.9			5.5			

of oxygen was probably the cause for the decreased purification with the lower rates of filtration. Figs. 4 and 5 illustrate that excellent purification can be obtained at rates of 8 m.g.a.d., resulting in about 95 per cent B.O.D. removal in 2½ hours with a 30 gallon batch. Optimum filtration rates may vary and factors influencing this variation will be discussed later.

Initial Load as Measured by B.O.D.—For this study two different volumes, 60 and 120 gallons, of the same sewage were circulated through the filters. The data are presented in Fig. 3. The filtration rates were

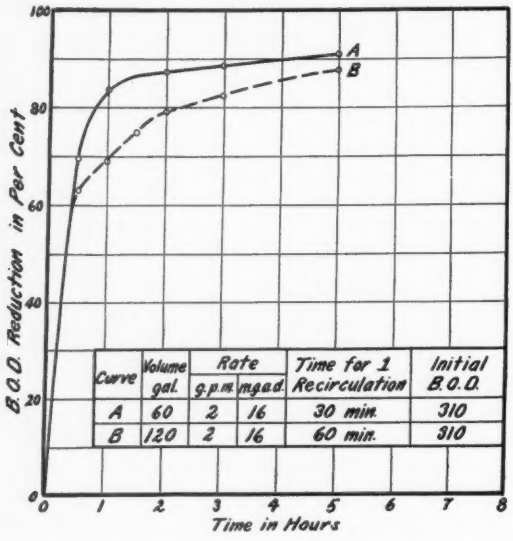
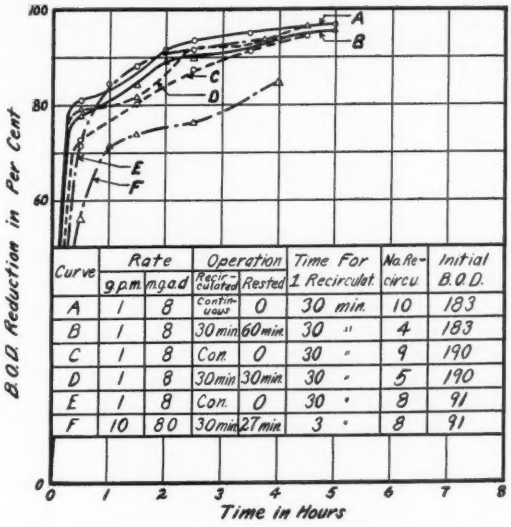

B.O.D. Reduction in Per Cent
Time in Hours
A
B
Curve | Volume gal. | Rate g.p.m. | Rate m.g.a.d. | Time for 1 Recirculation | Initial B.O.D.
A | 60 | 2 | 16 | 30 min. | 310
B | 120 | 2 | 16 | 60 min. | 310

FIG. 3.—Per cent reduction in B.O.D. obtained by recirculating 60 and 120 gallons of sewage at 16 m.g.a.d.

kept constant at 16 m.g.a.d. It was necessary to filter the sewage twice as long on the filter receiving twice the load in order to achieve results comparable to the one receiving the lesser load. For instance, 88 per cent B.O.D. removal was obtained in 2½ hours with 60 gallons of sewage while the same percentage removal required 5 hours with 120 gallons. Similarly, 70 per cent B.O.D. removal was obtained in ½ hour with the 60 gallon batch which is comparable to the removal obtained in 1 hour with 120 gallons. A direct relationship is apparent between the time of treatment and the load in pounds of B.O.D.

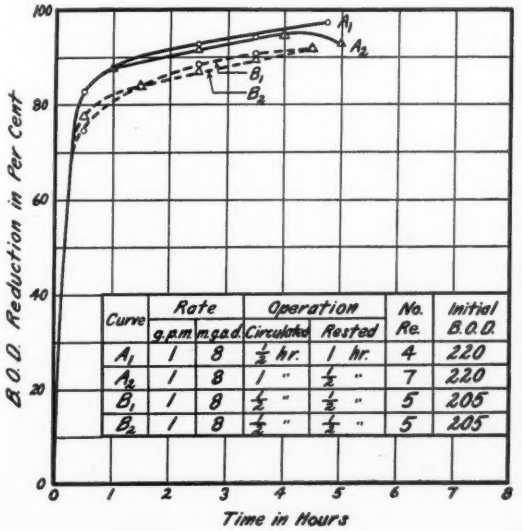
Number of Recirculations.—This factor was investigated by making several runs with similar loads of 30 gallons and the same rates of filtration. The numbers of recirculations were changed by operating one side of the filter intermittently. The results were most interesting as may be observed from the graph in Fig. 4. All the low rate dosage curves tend to approach each other or coincide, showing that the operation does not have to be continuous and that it is possible to obtain

efficient treatment with only two recirculations. For example, over 90 per cent B.O.D. removal was obtained in 2½ hours; one batch was circulated five times while the other batch was circulated two times during the 2½ hours with rest periods totaling 1½ hours (Curves *A* and *B*, Fig. 4). It must be stated that dissolved oxygen was present at all



Curve	Rate g.p.m.	Rate m.g.a.d	Operation Recirculated	Operation Rested	Time For 1 Recirculat.	No. Recircu.	Initial B.O.D.
A	1	8	Continuous	0	30 min.	10	183
B	1	8	30 min	60 min.	30 "	4	183
C	1	8	Con.	0	30 "	9	190
D	1	8	30 min	30 min.	30 "	5	190
E	1	8	Con.	0	30 "	8	91
F	10	80	30 min.	27 min.	3 "	8	91

FIG. 4.—Per cent reduction in B.O.D. obtained by recirculating 30 gallons sewage continuously and intermittently.



Curve	Rate g.p.m.	Rate m.g.a.d.	Operation Circulated	Operation Rested	No. Re.	Initial B.O.D.
A_1	1	8	½ hr.	1 hr.	4	220
A_2	1	8	1 "	½ "	7	220
B_1	1	8	½ "	½ "	5	205
B_2	1	8	½ "	½ "	5	205

FIG. 5.—Per cent reduction in B.O.D. obtained by recirculating two 30-gallon batches of sewage intermittently through same filter—filter dosed continuously.

times. Curve *F* which stands out by itself demonstrates the lower efficiency of the higher rates of filtration which provided short periods of contact in the filter and correspondingly longer resting periods.

That purification was not the result of the intermittent operation of the filter was shown in the following experiment. An arrangement was made whereby the bed was dosed continuously by two separate batches that were intermittently passed through the bed. The results obtained by this manner of procedure are presented in Fig. 5. They compare very favorably to the results shown in Fig. 4, and show that discontinuous recirculation is as efficient as continuous circulation.

Fig. 2 shows the per cent B.O.D. removal plotted against number of recirculations for the 150 gallon series and again it is evident that a minimum number of circulations may be satisfactory. As shown by curve *A*, 90 per cent B.O.D. removal was obtain with only 2½ recirculations.

Total Time of Treatment.—Results of the time of treatment are evident from all the graphs showing the B.O.D. removals. Rapid removal occurs within the first 2½ hours followed by a gradual increase over long periods of time.

Contact Time in the Filter.—The effect of seeding or contact time in the filter bed is shown in Fig. 6. Two batches of the same sewage were

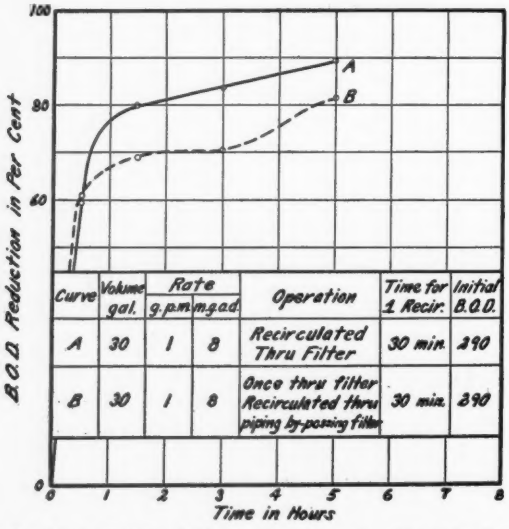


FIG. 6.—Per cent reduction in B.O.D. obtained by recirculating "A" batch through filter continuously and "B" batch through filter once and then by-passing filter bed.

used on the filters. One batch was recirculated continuously through the filter, while the other batch was passed through the filter once and then recirculated through piping by-passing the filter bed. Dissolved oxygen was maintained in both cases. Curve *B*, showing the results of passing sewage through the filter once in ½ hour and then recirculating

through piping by-passing the filter, illustrates the fact that seeding probably occurs while passing through the filter once and purification continues in the detention tank. A comparison between curves *A* and *B* indicate that under the conditions of this test, one passage through the filter doesn't provide sufficient contact time for absorption and seeding and results in lower purification as compared to that obtained by continuous passage through the filter bed.

Discussion

The operation of any biological process is dependent upon several fundamental conditions. Of these conditions four appear to be of prime importance: (*a*) Material to be treated; (*b*) Total time of treatment; (*c*) Dissolved oxygen content; and (*d*) Contact time with the active media. Most of the factors affecting purification by a biological filter may be traced to their influence upon these fundamental conditions. This is evident from a list of factors given by Hall [10] that include the size, character, and depth of media, temperature of air and sewage, strength and volume of the applied load, ventilation and cleanliness of the media, method of distribution and seasonal variations. Metcalf and Eddy [11] sum up filter purification under "Contact Phenomena" including mechanical straining of the larger suspended matter, adsorption, activity of living organisms and their enzymes at contact surfaces and the maintenance of proper conditions by the adequate supply of oxygen.

Seasonal or even weekly or daily variations of the sewage influence treatment results. This variation in the ability to treat sewage may be due to the varying degrees of availability of the organic matter or to temperature changes stimulating or depressing the activity of the organisms. This factor limits the accuracy of experimental data when comparing notes obtained over a long period of time. It is the intention of the authors in this report to indicate trends rather than to compare individual runs. Most of the comparable data shown in this report were usually completed on the same day or possibly the next day thus eliminating the factors brought about by the characteristics of the material and temperature variations.

Loading also plays an important role in filter operation. The B.O.D. removal is greatly influenced by the load and usually increases with the load although the effluent becomes progressively poorer. Accordingly sewages of similar characteristics and B.O.D. values must be utilized for all comparisons.

One important factor in filter operation that is often neglected, is the total time of treatment. The value of treatment time is clearly demonstrated in all graphs presented in this paper. Purification progressed rapidly for about 2½ hours and thereafter increased gradually over long periods of time. In 2½ hours over 90 per cent B.O.D. removal was obtained in many cases. It is evident that time of treatment is a more important factor than either rates of treatment or numbers of

recirculations. This is clearly shown in Fig. 2 where, regardless of rates or recirculations, optimum purification occurred within 2½ hours. It appears from the results reported herein (Fig. 3) that, to obtain a given effluent, the B.O.D. load in pounds is a determining factor for the treatment time. Eldridge [7] noted that the extent of recirculation for any desired effluent was dependent upon the B.O.D. strength of the waste. Jenks [8] found that a sewage requiring 6 hours aeration with activated sludge will generally require 6 hours recirculation through a system of biofilters to produce final effluents having comparable physical and chemical characteristics. It appears possible that with greater control, which can be obtained by the batch process, shorter treatment times are feasible. Campbell [12] believed that two hours recirculating through a filter might prove sufficient treatment time for sewage.

The maintenance of dissolved oxygen is another essential for the successful operation of any aerobic biological process. The effect of rates of circulation upon the dissolved oxygen is presented in Table I which contains D.O. data of the results shown in Fig. 2. An explanation for the poorer results demonstrated by curves *B* and *C* is quite evident. With low rates of filtration, D.O. was absent in *C* and appeared in *B* only after one hour circulation. Thus, purification was reduced in *C* because of septic conditions and lagged in *B* since D.O. was absent during the first hour.

Another demonstration of the effect of low rates and consequent absence of dissolved oxygen is illustrated in the data presented in Table II.

TABLE II.—*The Effect of Low Filtration Rates upon Dissolved Oxygen*

Volume in Gallons	Rates		Time of Treatment	Time for One Circulation	B.O.D.		B.O.D. Removal in Per Cent	Remarks
	G.P.M.	M.G.A.D.			Inf.	Eff.		
150	½	4	5 hrs.	5 hrs.	290	93	67.8	No D.O. in the Detention Tank
150	½	4	5 hrs.	5 hrs.	290	42	86.5	D.O. Maintained by Diffused Air

The low rate of ½ g.p.m. was chosen to reduce aeration and to maintain conditions such that D.O. would be absent. Great improvement in the removal of B.O.D. resulted in a parallel run when dissolved oxygen was maintained in the detention tank by diffused air. In spite of obtaining only one recirculation during the five hours of treatment, over 86 per cent B.O.D. reduction was obtained.

It is evident then that the rate of filtration affects aeration and that rates must be high enough to maintain sufficient D.O. in the liquor at all times, as oxidizing action can be obtained only under aerobic conditions.

Some other factors that may affect the dissolved oxygen content of the liquor are the temperatures of the air and sewage and the strength and volume of the applied load. Because of long recirculation times, the temperature of the sewage had a tendency to approach that of the air. A high residual D.O. was difficult to maintain during the warm

months because of the lower capacity for D.O. of warm water and the greater rate of D.O. use by biological life at higher temperatures. It may be necessary to increase filteration rates during the summer months to compensate for increased biological activity and lower oxygen absorption ability of the warm liquid.

Halvorson [14] noted that a temperature differential of 4° C. between the sewage and air was necessary to cause an air current of 1 cu. ft. per sq. ft. per minute. In this work a complete record of temperatures on both air and sewage was taken every half hour. Differences between the two temperatures did not seem to influence the D.O. content of the liquor.

Loading is another factor affecting dissolved oxygen. As the load on the filter increases more oxygen is required and a reserve is difficult to maintain.

Of importance in the successful operation of the recirculating filter is the contact time of the sewage in the filter bed. This contact phenomena, as previously mentioned, includes mechanical straining, adsorption, and seeding. That adsorption and filtration occurs is evident from the results that indicate a rapid purification within the first hour and at times within the first half hour. This rapid removal appears to be dependent upon the contact time as shown in Fig. 2, where curve *E*, in spite of the sewage passing through the filter every 7½ minutes, required over 1 hour to obtain the large initial purification. In fact, as the filtration rates increase contact time and possibly seeding diminish, a condition which may be further aggravated by short circuiting resulting in correspondingly higher actual rates. It appears that under the conditions of this experiment that 24 m.g.a.d. is approximately the maximum rate at which sufficient contact time was obtained.

That seeding occurs along with other contact factors during a single passage of the sewage through the filter bed and is followed by purification in the detention tank is demonstrated by curve *B*, Fig. 6. Sixty per cent B.O.D. removal was obtained in one-half hour after a single passage through the filter and purification proceeded in the detention tank resulting in over 80 per cent B.O.D. reduction in 5 hours. Comparing curves *A* and *B* of Fig. 6, it appears that one circulation through the filter bed provides insufficient contact time for maximum purification while Fig. 4 illustrates that two recirculations were sufficient.

The action of the filter under high filtration rates is that of a flocculator or colloider and the solids are washed continuously from the filter bed. The solids appear more granular than activated sludge and settle rapidly. No difficulty should be experienced in dewatering the sludge.

Summary and Conclusions

An experimental filter plant treating sewage by the recirculating filtration process was operated on the batch basis to obtain fundamental data. It is demonstrated:

1. The initial load, as measured by B.O.D. in pounds, influences the time necessary for treatment of sewage. A direct relationship appears

to exist between the period of treatment and the B.O.D. load in order to obtain effluents of like qualities.

2. The treatment time of all biological processes is of vital importance. It is possible to obtain over 90 per cent purification in 2½ hours with domestic sewage. Purification increases slowly with time after the initial purification is obtained.

3. Dissolved oxygen is essential throughout the system in order to maintain aerobic conditions and so obtain maximum purification.

4. Filtration rates must be such as to maintain ample amounts of dissolved oxygen in the liquor so that an aerobic condition throughout the entire system is assured. Low rates of filtration do not cause sufficient agitation for proper aeration while high rates decrease the contact time during passage through the filter bed, thus reducing adsorption and seeding which in turn results in decreased purification. It appears that the minimum rates of filtration conducive to the maintenance of dissolved oxygen produces the best results. Sufficient contact time was obtained with rates as high as 24 m.g.a.d. under the conditions of experimentation.

ACKNOWLEDGMENT

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Operators' Reports and Suggestions

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METHODS AND PROBLEMS OF SEWER MAINTENANCE *

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Maintenance methods and problems deal with all wastes entering a sewerage system, or to the steel, concrete, iron or whatever may be used as a carrier for the waste matter in its proper treatment and disposal. "Maintenance is the art and science to preserve," [1] by keeping all structures, pipe lines, pumping plants and disposal plants in first class operating condition. It is this problem of maintenance in which we are interested.

Sanitary engineers have devoted most of their time to treatment and disposal of sewage, forgetting to some extent that part of the disposal problem which begins at the house or industrial connection.

Maintenance really begins with the design and construction of the sewerage system. Thirty years ago this might not have been true as sewer maintenance consisted mostly of "trouble shooting," pipe line stoppages, and when machinery broke down to replace it while the sewage was by-passed to the most convenient location for disposal. Today, due to the evolution or progress of living conditions, the rapid growth of communities, and the forward stride of sanitation, the closest kind of co-operation is necessary between the design, construction and maintenance divisions. The results of new methods, new types of construction and changes made necessary through field conditions should all be reported to be common knowledge of all concerned, so greater efficiency in maintenance may be obtained. "In fact this co-operative and harmonious relations could exist to the point that when sewer bond issues or sewer appropriations were considered they could be stretched just a little to include new maintenance equipment" [2] or increased personnel per mile of sewer or plant added to the system.

In order for the above co-ordination between Divisions to exist there should be "Uniform Sanitation Records." [3] In years past many employees in all parts of the nation on maintenance work were known for their ability to remember what happened fifteen or twenty years ago with the result that much valuable information was lost. Keeping records on maintenance work should be one of the first duties of operators

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and employees; as the principal concern of public officials, civic associations and tax economy leagues is the results of the work and its cost. These records should also show that proper maintenance has been given and equipment operated the way it was designed to function, and at all times be at the disposal of the designing engineers.

Maintenance Work

In the City of Los Angeles, the Sewer Maintenance Division has charge of the maintenance and repair of all sanitary sewers, storm drains, culverts, flush tanks, sewage and storm water pumping plants, ventilating plants and the Hyperion sewage screening plant, also the elimination of storm water from the sanitary sewerage system, the elimination of explosive gas and detrimental industrial waste from both sewers and storm drains and the control and maintenance of open storm water channels.[4]

The sewer and storm drain system consists of 2,794 miles of sewers and 11,599 flushing structures, 630 miles of storm drains with 26,200 catch basins, 632 culverts, 18 pumping plants, one storm water pumping plant and a sewage screening plant.

The personnel consists of 134 persons subject to twenty-four hours service when necessary, due to emergency work at time of storms, pipe line stoppages or plant failure.

Systematic Maintenance.—In this article only one phase of the maintenance work and its cost will be considered and that is pipe line maintenance, in the effort to keep sewers and storm drains clean, sanitary and unobstructed, so that full efficiency may be obtained, "the preventing and removing of deposits, and the maintaining of ample and safe ventilation."[5]

This maintenance is the protection given an investment by the citizens over a period of years of about sixty-five million dollars, and serving an estimated population of 1,500,000.

In the planned maintenance program it is essential that systematic inspection, cleaning, and flushing should be done as a preventive measure not waiting until reports of stoppages or breakdowns occur.

The city is divided into approximately 350 sewer districts each of which has a corresponding map number, which map shows all streets, rights of way, location, size, elevation and grade of sewer, location of manholes and elevation of street surface.

Each of the six yards located in different parts of the city has a copy of these maps for sewers and storm drains, which are given to the crews as work is assigned in the various districts. A monthly record is kept on a key map in the main office when these inspections are made. Through this systematic inspection the entire sewer system is gone over every six months. Bad sewer locations are recorded and given the necessary maintenance for their proper functioning.

The sewers are constructed to flow by gravity on grades that will give a self-cleaning velocity which should be between two and seven

feet per second. Experienced personnel are able to determine by inspection when clogging or deposits are occurring and that sewer is then rodded and cleaned and the obstruction removed.

Daily time sheets show work done, time on each class of work and materials used. A monthly recapitulation of time and work is made which on a graph chart shows the division of time spent, or any sudden increase or decrease on various classes of work.

Field Crews and Trucks.—Twenty-nine field crews, equipped with trucks maintain the sewage system. A crew consists of one foreman and two or three men. These trucks are of 1½ ton canopy type and carry about $500 worth of tools for maintenance work such as 350 feet of all types of sewer rods, 500 feet of 2½ inch fire hose, hooks, cutters, spears, scoops, augers, self-propelling, revolving nozzles, picks, shovels, bars, gads, buckets, lanterns, flash lights, rubber sand cups, mirrors, spot lights with 50 feet of cord, rope, safety belts, hydrant wrenches, rod wrenches, hammers, sledges, small tools, beach balls, and rubber hip boots for each member of the crew. These trucks are equipped with trailer hook for hauling pumps, and five dump trailers are used for catch basin cleaning on light pick-ups. Some of the trucks are equipped with 120 volt electric generators which are used to operate an electric driven fan for ventilation of manholes and pipes lines that have dangerous gases and obnoxious odors.

These generators also operate an electric drill, hammer or saw and will operate 15 or 20 electric lights for night work or inside pipe work.

All automotive equipment used has been operated on the average of 212,000 miles per year at a cost of about 4 cents per mile. Automotive control by oil analysis is used for truck operation which gives an opportunity to make minor adjustments and repairs before there is a serious break down and keep trucks in service without delay. This same control is used on all portable and stationary gas engines.

Cleaning and Rodding.—Cleaning and rodding of sewer lines is necessary only when there appears to be a clogging or a stoppage in the line, breakage of pipes and bad odors. This may be caused by deposition of sand, rags, grease discharged hot into a line which, on becoming cool, is deposited in thick layers on the pipe, fungus growth where periodic flushing has been neglected over six months, corrosive acid or chemicals disintegrating cement pipe, tarry and oil deposits from manufacturing plants forming tough greasy masses, gas residue from tanks, steel filings, broken bottles, cement washings, concrete and brick from construction work, improper use of toilets over manholes, soap, lime deposits, and scale from boiler waste and roots. Broken sewers are caused by excessive superimposed loads, unsound foundations, undermining and progressive deterioration.

In cleaning, iron rods of ⅝ in. black pipe fitted with special screw couplings with hexagon collars at one end for use of a wrench, are used for slow heave hand work. Wooden rods are the regular round standard hickory rod with slip coupling and are used for light fast hand work when slight obstructions appear in the line. Heavy wooden

"Jumbo" rods are used mostly on storm drains from the outlet pipe to catch basins. Flexible steel rods which are manufactured locally have a ratchet wrench attachment that enables the operator to turn the rods as they are pushed into the sewer. They are also provided with guides which enable them to be worked from the surface when a manhole is full or partially full of sewage. This is called the cool easy way. Straight and self propelling nozzles are used for cutting and can be inserted as much as 300 feet into a sewer. Beach balls that will fit snugly in pipes are inserted into the outlet of an upper manhole and with hydraulic pressure caused by backing up of the sewerage around the ball, the accumulated substance is cut ahead of the ball, cleaning the line. Sand traps with one-quarter bend are placed in the manhole ahead to catch heavy material washed out. Rubber cups attached to rods are also used for this purpose in the same manner as the beach ball. In large sewers a canvas "kite" attached to a cable has been effectively used. Care should be taken that sewage is not backed up through the house connections when cleaning in this manner.

Besides hand cleaning the city has one of the first Werko power sewer sweeps. It is a portable machine which carries about 500 ft. of 5/16 in. special oil tempered spring wire wound on a reel, the reel being mounted on a carriage which rotates around on an axis perpendicular to the real axis with steel fingers meantime feeding the wire out or in through a curved pipe extending from the machine, through a manhole into the sewer. The forward end of the wire carries any kind of a cutting or cleaning tool desired, revolving it at any desired speed up to 750 r.p.m., and moving it forward and backward at any speed up to 100 ft. per minute. The power unit is an eight cylinder gasoline engine. This machine cleaned 413,703 feet of sewer in one year at an average of 254 feet per hour of working day. The cost of this type of heavy work was 3½ cents per foot of sewer cleaned.

Storm drains are systematically maintained the same as sanitary sewers but require a different type of maintenance work. The principal work required is that of cleaning catch basins and culverts. All large drains are inspected twice a year, in the fall before the rains and in the spring. Catch basins and laterals are inspected and cleaned when necessary on a daily, weekly and monthly schedule, depending upon local needs. In pipe large enough to permit a man to work, material is removed by shoveling into a bucket or wheeled carrier, moved to the manhole, and raised to the surface and dumped. The Champion self loading bucket is used where pipe lines are too small for men to work inside, the bucket being on a cable operated by a gasoline engine on the street level above. The cost of the work of cleaning is .305 cent per catch basin, .017 cent per foot of culvert and .007 cent per foot of storm drain.

Construction and Repairs

Maintaining sewers also includes the necessary construction and repair work. This work is generally more difficult to perform than the original construction work. On excavating a second time the ground is loose and more difficult to hold and is usually saturated with sewage. Such construction is generally of an emergency nature and in the business and congested districts and often has to be done at night. Repairs common to the sewer system are replacing manhole covers, street inlets or catch basins broken by traffic or through progressive deterioration, raising and lowering of sewer and storm drain manholes and catch basins caused by settling or raising of the pavement and also subsequent fills or cuts in the streets, replacing of broken pipe, replacing loose brick and mortar which has dropped out, repairing of manhole bottoms and plastering the inside to prevent deterioration due to gases, replacing manhole steps; locating and replacing house connections in city streets, excavating for and laying relief lines to ease overloaded conditions; excavating and opening up lines due to stoppages in line and relaying and cleaning same; tunneling into fills to replace crushed pipe due to settlement or improper reinforcing, storm damage construction and repairs due to flooded conditions, minor repairs and pulling of pumps; and experimental construction.

The cost of this work for one year is as follows.

Sewer Repairs	$15,224.98	Cost per mile in service	$5.49
Storm Dr. Repair	5,557.20	Cost per mile in service	8.82
Sewer Construction	6,408.09		
Storm Drain Constr.	8,152.98		

Manhole Covers

Constant complaints are received on account of noisy and loose manhole covers. There are about 70,000 manhole covers in the city of all types. Different methods have been used to stop noisy manholes by placing different materials to cushion the covers, some of which are quite costly and have not been very satisfactory. An application of hot tar has given the best results but it has to be renewed from time to time. Locking manhole covers are being specified at the present time but the removing of the cover slows down maintenance inspection. The newspapers have carried notices telling citizens to call and noisy covers will be replaced or repaired. This has increased the number of noisy manhole covers sealed. In 1938 there were 2,815 and in 1939 there were 1,833 at an average cost of $2,907.20 for the year or 1.58 each.

On the following page is a tabulation of our recent maintenance costs.

The total cost per mile of sewer lines in service for inspection, cleaning and replacing is $20.06. For storm drain maintenance, inspection and cleaning and repairing it is $71.62 per mile in service.

YEAR, 1939

Type of Work	Work Done	Cost	Cost per Mile in Service
Sewers			
Sewer Stoppages	95	$1,151.10	$0.41
Sewer M. H. Cleaned	13,435	4,163.21	1.49
Sewer M. H. Inspected	134,991	18,044.71	6.46
Miles of Sewer Inspected	6,798		
Miles of Sewer Cleaned	204	14,345.80	5.13
Miles of Sewer Flushed	126	1,464.27	0.52
Storm Drain			
Catch Basins Cleaned	56,479	23,300.69	36.99
Miles Culvert Cleaned	72	7,747.61	12.30
Miles Storm Dr. Cleaned	158	6,395.65	10.15
Miles Storm Dr. Inspected	137	1,691.83	2.69

SEWER FLUSHING

The same systematic inspection used on pipe lines is used in the maintenance of the 11,599 flushing structures. The combined method of flushing sewer pipe lines, inspection and cleaning seems to be the best procedure in the City of Los Angeles sewerage system. There seems to be many differences of opinion as to the method of flushing either with automatics, hand flushing, flushing with fire hose or water wagon. All four methods are used as the conditions require because, "sewers must be flushed to remove and prevent deposits, which becoming putrescent would produce noxious and offensive gases and eventually cause choking of the system."[6] Putrefaction does not set in usually until after a period of twenty-four hours; and in a well designed system the sewage should never take a longer time than this to reach the outfall, treatment plant or point of disposal. A sewer that has been laid at a grade that is self-cleaning only when running half or one-third full which may not be the normal state of affairs may need daily flushing to prevent deposits and render the sewer air unobjectionable. "Flushing helps get rid of sulfur compounds which are a considerable factor in causing unusually high H_2S readings as proper flushing not only adds water giving the proper velocity for scouring but it sucks in air causing better ventilation."[7]

At the present time there are six types of automatic flushers used in the city and the regular hand operated flushing manhole. Six field crews of two men each with trucks and one shop crew who recondition equipment with an office clerk and a foreman maintain all flushing structures in the city. All flushing structures are numbered by the design division when constructed, at which time the type of apparatus is installed as required by the contractor during construction. Inspection and repairs in the field are made from daily work schedules assigned each crew and a report made showing time spent, work done and materials used on each tank. This is posted on a report card from which the monthly reports are made out. This report card shows the number

of the tank, when installed, when inspected, condition found, repairs made, work done, condition left and condition of the water service. Besides the report card there is a card file by number and location and also another card file by location and number of all structures. Work in the field consists of cleaning, renewing of parts, if any, installing or dismanteling and plain inspection, or check of condition.

Automatic flushers are installed on flat grades and hand flushing is used on 1.6 per cent grades or more.

Automatic flushers operate daily, dumping 300 gallons of water every twenty-four hours while manual operated flushers are flushed once in from four to six months using 500 gallons of water per flush. Hand flushers are operated by turning on ten or more tanks, then going back and flushing and shutting the water off when full. Materials removed by flushing are fine sand, coarse sand, road detritus, ¼ in. to 2½ in. broken stone and gravel and whole brick. "This material would form a stoppage unless flushed to the trunk line of the sewer system where the velocity causes continuous suspension and has the required transporting power."[8]

Water services are maintained inside the tank by the flushing crews on private water companies' lines but the Bureau of Water Works and Supply inspects and maintains the service to see that the water jet meter is given the required amount of water on automatic tanks each day on city water lines. Monthly check of Water Department records is made against the report card to get the total amount of water used each month.

There are 6,579 automatic flushers operating at the present time. There are 2,483 manually operated tanks in service. The cost of operating automatic flushers of all ages of service from ten years to thirty-two years, is thirty-five cents (.35 cents) per month or $4.20 per year per structure. The cost of hand flushing per structure is .76 cents per year.

Gas Survey

Danger lurks under the street. Manholes have blown up, streets have been torn open by explosions, pumping plants have been wrecked by the explosions of gases coming from sewer and storm drain lines. The vital arteries of the modern city are sealed in by gas tight pavements. Underneath this seal, inflammable gases may leak from mains and enter into any portion of the sewer or storm drain structures. Industrial wastes such as crank case oil and such petroleum substances as benzine and gasoline find their way into the sewer from storage and service stations and garages, and probably from dyes and cleaners and other manufacturers, thus creating a gas hazard.

In order to prevent explosions and eliminate dangerous locations the maintenance division has a gas survey crew composed of two men and a package truck for field work. A systematic procedure of testing manholes is used, the entire city being worked by sewer district maps as the planned maintenance program requires. The Union Carbide

Company's combustible gas indicator and also a Mason gas leak indicator are used and kept in working condition by the gas survey foreman. A daily and monthly record is made of all sewer districts tested, number of manholes inspected, conditions found, dangerous locations and date reported. A card index is kept of all dangerous locations, date tested, when Gas Co. has been notified, when rechecked, when repaired. When very dangerous conditions are found the sewer district foreman and superintendent and the utility company are notified immediately. This method of maintenance with the equipment provided has made it possible to increase the manholes tested from 1,000 per year to 5,000 per month, or 60,000 manholes tested per year. This nearly covers the entire city each year.

Safety measures and instructions are issued to all maintenance employees, concerning entering manholes, use of safety belts, lights in or near structures, use of cannister and hose type masks, ventilating to reduce dangerous gases, use of water to clean air, instructions on first aid and simple tests for detecting poisonous gases such as silver coin, strips of polished brass, or paper dipped in sugar of lead solution.

The following procedure helps eliminate explosive hazards and dangers in manholes and sewers.

1. Systematic inspection, using gas detector.
2. Elimination of illuminating gas leaks.
3. Proper disposal of inflammable liquids by inspection of gas and oil filling stations, garages and repair shops.
4. Ventilation.
5. Protection on entering sewer manholes.
6. Filling in cavities or unused structures.
7. Investigating complaints of odors and following up those that are considered of a dangerous nature.
8. Co-operation between city and utility companies.

Ventilation

Ventilation is important for the proper maintenance of sewers. "The operator of the disposal plant wants sewage delivered to him in an aerobic condition, and it is no excuse to say the distance is too great. In a fast flowing sewer many miles long aerobic conditions can easily be maintained by ventilation; but if it is deliberately closed up so that fresh air is no longer available the maintenance of aerobic conditions are practically impossible. When there are complaints of smell, such conditions discloses the need of more ventilation, so let the smell out by letting the air in."[9]

Wet side walls in a manhole are a sign of poor ventilation. In small pipes or separate systems if an effective inlet is provided by vented manhole covers, sufficient outlet is provided by the house stack vent. Placing traps in house connections, sealing manholes because of odor or noise, so air cannot be sucked into the sewerage system is poor practice, but in a great many cases it is necessary.

In large outfalls forced draft seems to be necessary and at the present time two such ventilation stations have been constructed on our outfall sewer for experimental purposes. In the very near future the design division will have several ventilator plants ready for construction, where the "required number of air changes per time unit will be attained, which is the science of air ventilation and corresponds to the process of nature." [10]

Conclusion

All functions concerning sanitation are interlocked and work together. As changes are occurring in modern scientific research, people are realizing through news items and public relations programs the part that proper sanitation may play in preventing premature death and in making life more pleasant.

The Sanitary Division and Disposal of Waste is under the direction of Mr. H. P. Cortelyou, Deputy City Engineer of Sanitation and Mr. F. A. Batty, Superintendent of Sewers. Mr. Lloyd Aldrich is City Engineer.

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DISCUSSION

SEWER MAINTENANCE

By Fred D. Bowlus

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In the maintenance of a sewerage system designed for disposal of domestic and industrial wastes, continuous uninterrupted flow is an all-important function. It is seldom possible to shut off a sanitary sewer for any length of time, and it is costly to construct and operate a by-pass. Eternal vigilance is also required to prevent, so far as possible, the inflow of storm water, since this would reduce the designed capacity. In a metropolitan area, street work and public utility construction and maintenance must be closely followed to prevent impairment of the steady sewage flow.

Protection of a sewer structure from internal disintegration is insurance on the original investment. This attack from within is largely due to acids, either diluted with the sewage itself or formed on the

walls above by sulfur-splitting bacteria. Remedial measures can only be adequately applied when knowledge of the system is acquired through tests of the sewage and sewer air.

The Los Angeles County Sanitation Districts now maintain 200 miles of trunk line sewers, varying in diameter from 8 inches to 10½ feet. Feeding into this system are over 500 miles of sewers maintained by Los Angeles County, and 750 miles of local lines serving 23 incorporated cities. After twelve years of operation, the ever-increasing sewage flow will total 30 m.g.d. before the end of 1940. Materials used in the construction of the trunk line system have included vitrified clay, concrete and reinforced concrete. Several miles of monolithic structures were so installed. These were lined with a glazed tile facing, using a special joint compound.

A crew of two or three men make occasional tests of sewage and air conditions, the data being used for sulfide control and general administrative purposes. Every mile of the County Sanitation Districts sewerage system is thoroughly cleaned at least once each year and some more often. Three-man crews seem to be the most efficient, operating from a Ford truck. Although removal of sludge, slime and sand are most important, a considerable amount of brick spalls, wooden blocks and metals are also recovered. Lines up to 24 inches in diameter are cleaned by passing balls through the pipes. Two or three layers of burlap are sewed onto heavy rubber balls and a rope bridle attached. The ball is propelled by the sewage itself. However a rope, paid out from an apparatus at the manhole top, retards the ball sufficiently to give the desired jetting action ahead. Wear on the rope as it makes the right angle turn into the pipe from the manhole above, is prevented by a portable mounted pulley. A light hardwood snubbing winch fitted over the manhole rim provides simple control of the rope tension. As the ball nears each manhole, it is temporarily stopped with a wooden disk and a prop, while the debris is shoveled into a bucket and hoisted.

In pipes with diameters between 27 and 48 inches, a wooden disk slightly smaller than the pipe is used. The disk is held upright by a 4 in. × 4 in. wooden tongue extending aft, strap irons being bolted to its end to maintain the timber horizontally. Segments of tire casings nailed to the disk rim streamline the apparatus. These disks also do a more thorough job of cleaning when restrained by a back stay rope. In the larger structures a hoe type wooden drag with a tongue floating astern, built only high enough for the particular sewage flows encountered, has been used with success. Several hundred pounds of concrete blocks are often attached to the blade to prevent its skipping over sand and other debris. These hoes have removed hundreds of tons of sand from the outfall sewers. A portable gasoline engine hoist and self-dumping bucket are used in all cases where any considerable amount of debris is to be removed from manholes. In general, time has been saved and a more thorough job done by removal of material at each manhole rather than attempting to push it ahead for any distance. Jointed flexible steel rods are available in the rare case of a

ball getting stuck. These are readily punctured and dragged out with a cork screw attachment. Root growths in sewer pipes occur at very few points in the district trunks. Frequent cleaning with a ball prevents growth to any extent. Special tools are sometimes passed through lines where oil field wastes leave hard deposits. Only rarely does an initial head of water have to be purchased at the upper ends of trunks to propel a cleaning ball.

Although ropes and leather belts are always available in sewer maintenance work of the County Sanitation Districts, they are seldom needed because of the thorough knowledge of sewer air conditions throughout the system. The field cost of cleaning 55 miles of sewer in 1940 amounted to $30 per mile.

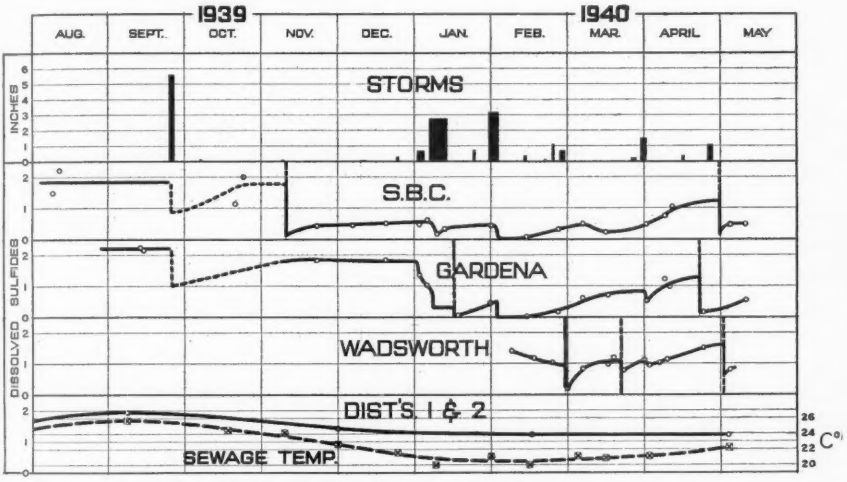

FIG. 1.—Tests for dissolved sulfides in three typical trunk sewers to determine the effects of sewer cleaning and natural storm water flushing.

The maintenance crew is also called upon to inspect all local sewers and house connections to the trunk system, and make occasional measurements of the sewage. The Districts have developed the Venturi-flume for the latter purpose. Some installations of concrete are made, but three-piece portable sheet and cast iron flumes are used extensively. Ingenious ball-bearing devices for accurately transferring float levels to stage recorders, and cams to convert the logarithmic water level-flow ratio so that it will fit the regular commercial cross-sectional record paper on these machines, have been devised.

The crews also make minor repairs to sewers, adjust manhole rings and covers to fit new pavements, and make major repairs at the Districts' twelve sewage pumping plants and eight chlorine stations.

The period between cleaning operations of a sewer depends on several factors: sewer grades, velocities, quantity of sewage, pipe materials, lateral flushing, and storm water flushing. During the past year, tests for dissolved sulfides in the sewage have been taken on three

typical trunk sewers to determine the effects of sewer cleaning and natural storm water flushing. These data have been plotted as Fig. 1. Each point on the graph represents an average of continued testing for several hours throughout a period of the day when the sulfides were highest. However, the points for the combined sewage in the Joint Outfall from Districts Nos. 1 and 2 are averages of continuous 48-hour runs. Insufficient data were taken to show the true effect of the unprecedented storm of Sept., 1939, but by comparison with later storms of the past winter it has been assumed that a flushing effect materially reduced the sulfides for a period. That the sulfides again returned is shown by tests on both the South Bay Cities and Gardena trunk sewers. Thorough cleaning of the South Bay Cities trunk in November, 1939, caused an immediate reduction in sulfides and they have remained relatively low for nearly five months, the situation having been aided somewhat by at least two later storms. In the case of the Gardena trunk sewer, sulfide production was stopped by a combination of storm and sewer cleaning in January, but the beneficial effect lasted only about six weeks. However, the sulfides found in March were probably not as high as would have been the case without the sewer cleaning or storm flushing. Sewer cleaning on the Wadsworth trunk has been effective in reducing the sulfides for apparently only a matter of a few days.

In the South Bay Cities trunk, sulfides were being generated last fall within the trunk line itself before it was cleaned, due to deposits of sludge, slime and sand, as no tributary of any importance entered the line carrying sulfides. Here cleaning had a lasting effect. In the case of both the Gardena and Wadsworth Avenue trunk sewers, further tests have revealed that a number of contributing laterals carry sulfides. A large portion of the Wadsworth Avenue trunk sewage enters the trunk with sulfides one and one-half miles above the point where records were obtained for the curve. Industrial wastes with sulfides entering at another point also raise them. Sewage flow during the time of sampling in these trunks averaged:

South Bay Cities	2.0 M.G.D.
Gardena	0.4 M.G.D.
Wadsworth Avenue	0.6 M.G.D.

Tests on these lines will be continued throughout the summer, but sufficient evidence is now available to show that sewer cleaning materially reduces the sulfides.

If those laterals carrying sulfides were periodically cleaned, or possibly flushed, control would be aided.

Thorough cleaning of the County Sanitation Districts trunk sewers has necessitated men entering every manhole in the system and occasionally traversing the sewer itself between manholes. A knowledge of both the sewage and sewer gas has been paramount to the employees' safety. As a result, only minor accidents have occurred during the ten years this work has been under way. Eternal vigilence is necessary and the problem of safety has been more difficult because of intermittent

strong industrial wastes. Tests of the sewer air have been made occasionally to trace the extent and concentration of hydrogen sulfide gas, depletion of oxygen and explosibility. Both commercial gas and gasoline have detectable odors, and in this case no one is allowed to enter a structure without further ventilation. Release of hydrogen sulfide gas from the sewage depends on several factors; *i.e.*, concentration, velocity and pH. Twenty p.p.m. of this gas have been observed in the sewer air where a vertical drop exists in the invert, even when the sewage had less than 0.5 p.p.m. of dissolved sulfides; and in other sewers where the velocities were low and no turbulance occurred, only traces of the gas were found in the air even when the sewage carried two to three p.p.m. of dissolved sulfides. Turbulance is a major factor in hydrogen sulfide release.

At one manhole, sewage from a lateral with 3 to 5 p.p.m. of dissolved sulfides dropped into a trunk with none. Hydrogen sulfide in the air was 60 p.p.m. at that manhole, but only one-third that amount in a structure less than 100 feet away. This reduction was due in part to immediate conversion of the gas into sulfuric acid by bacteria on the sewer walls and in part to re-absorbtion into the larger flow of sewage in the trunk line.

The maintenance crews often work many hours each day in sewers with hydrogen sulfide concentrations of 10 to 20 p.p.m. Most authorities agree that 200 p.p.m. are tolerable, with signs of distress not noticeable until 500 p.p.m. are found. Of late tests show a maximum of 100 p.p.m. in the County Sanitation Districts system. A few tests of the Los Angeles City north outfall sewer show this is not exceeded in that sewer. Tests of sewer air have also revealed that high hydrogen sulfide usually is accompanied by oxygen depletion. Where 50 to 100 p.p.m. of the gas are found in the sewer air, oxygen deficiencies of five per cent have been measured. However, lack of oxygen may occur even when the hydrogen sulfide is low. One recent test of a structure where a man had been overcome some years ago, showed only 12 per cent of oxygen when less than 1 p.p.m. of hydrogen sulfide was measured in the air.

Because the sewage of Southern California has a higher temperature (20° to 26° C.) than in more northern climates, operation and maintenance of a large sewerage system here usually requires control of sulfides in addition to the ordinary work. Efficiency depends upon the diligence with which the problem is attacked. Two men of ordinary intelligence may readily be taught the methods of sewage testing, and even though only part of their time is devoted to this work, will obtain a surprisingly comprehensive picture of a system in a few months. The apparatus is not expensive. The County Sanitation Districts have demonstrated that thorough cleaning of their trunk sewers has materially aided sulfide control. As a result of further research and recent adjustments in the chlorination program, sewage enters the head of the Joint Outfall sewer from the several districts with practically no dissolved sulfides at any time. Complete protection of this large out-

fall structure for its entire length of seven miles, and odor control at the Joint Disposal Plant, will be effected in the near future. Studies on the treatment of sewer air by ventilation and by application of ammonia gas are nearly complete.

THE MAINTENANCE OF SANITARY SEWERS IN SAN DIEGO, CALIFORNIA

By Byrl D. Phelps

Assistant City Engineer, City of San Diego, California

The City of San Diego, California, is situated along the Pacific Ocean and Bay of San Diego. The land adjacent is traversed by canyons and sloping drainage areas. In many cases the sanitary sewerage systems were put in as units to serve each particular section of the city as the building of structures demanded sewers. These small trunk lines emptying into septic tanks and creek beds were later joined together with trunk sewers and discharged into the Pacific Ocean through outfalls and into the Bay of San Diego through outfalls. In April, 1940, there were 525 miles of sanitary sewers serving a population of 180,000 to 200,000 persons scattered over an area of 21 miles in length from northerly city limits to the southerly boundary line of the City of San Diego.

The City of San Diego has provided a Division of Sanitary Sewers consisting of the following personnel to maintain this system only: one acting superintendent, one district foreman, two crew foremen, three acting crew foremen, four plumbers, two sewage pump mechanics, and 30 laborers. The city engineer's office co-operates with the above personnel on special problems.

The Division of Sewers has the maintenance of all the sewers in the City of San Diego. The construction of sewer laterals in unpaved alleys and streets and the connection of the sewers from the property line to the trunk sewers also comes under this department. In some cases short extension of sewers are made by this department. The charges for this work are $15 for sewer laterials in dirt alleys, $30 for paved alleys, $30 for sewer laterials in dirt streets, and $50 for paved streets.

The maintenance of the sanitary sewage system begins at the outfalls and the following problems have arisen. First, the anchorage of the outfalls: This has been done with steel railroad rails but serious disintegration of the iron in salt water and sewage has caused portions of the outfall to break, allowing sand to enter the portion left and problem No. 1 enters the book as to how to remove the sand. The use of fire hose and water jets has proved successful in many cases, but in several instances the sand was packed so tight that this method was not successful. Sewer rods with special cutting blades have been used

with good results, but in one case at Mission Beach the rods broke in the pipe and a new problem was added—that of removing the broken rods.

One solution was found and that was to construct the smaller outfalls of genuine wrought iron pipe and install cleanout holes along the line with bolted plate covers. These may be utilized for cleaning purposes. At the end of the outfall two elbows were turned up. The entire outfall was wrapped in canvas strips and coated with a bituminous coating, then floated in place and anchored in the sand with chains. This line has some flexibility and has not given trouble from sanding up.

The settling tanks along the ocean are a constant maintenance problem. The emptying of sludge at the proper time to prevent odors has caused the ever ready excuse to let it go and then the tanks become overloaded with sludge, pipes cake up and it is impossible to empty the tanks after the valves are opened. It then requires the use of sludge pumps or hose on a jet to break up the solids. Vent pipes on the tanks are a constant source of trouble. Either the public is plugging up the pipes with sticks and stones or breaking off the goose-neck vents and plugging them up causing gas to form in the tanks. In some instances considerable odor has been noticed at the vent pipes, especially if the ocean surges into the outfall forcing air into the tank. Vents have been run up beside telephone poles and also disguised as lamp standards to try and detract the attention of the public—but a nice down draft and hydrogen sulfide is not so easy to hide.

The next problem is to get rid of the gases if possible. This was solved by installing a small plant to make ferric chloride at the pumping plant ahead of the settling tank and outfall.

Pumping plants are a nice useful part of a sewage system until something goes wrong. Poor ventilation will cause condensation on the ceiling and little drops of water on switches, wire terminals and motors, and finally trouble. Ventilation holes in the pump house located in the exact manner as needed turn out to be inlets for rain in a storm, and the result is a flooded motor at the time most needed.

The idea of a pump house vent in a residential district is not to be tolerated, but a vent disguised as a beautiful flag pole or bench is an asset to any community.

Pump house floats to operate the pumps are always easy to design and look well and neatly balanced in a catalogue but after a few weeks in a strong sewage some problems are sure to occur. The metal becomes corroded and so a new wood float is tried out; this is wonderful until waterlogged with sewage and then trouble begins; so the friendly glass jug with a cork is used with equally as small a chance of success. Now newer methods with electrodes are developing electrical gymnastic tricks to fool the operator.

Sewage pumps that pass all solids that are not held on bar screens are now constructed and operate until a small piece of wood 1⅞ in. wide and 6 in. long passes a 2 in. bar screen opening just so it can crowd into

the pump and stay wedged in place to defy all gauge readings, the search for tuberculation in pipes, and the undersize outlet and inlet pipes, back washes and every other known test until you decide a new runner is necessary and the little piece of wood is finally pulled out of a hole in the runner to end all trouble for the day.

The safest means of cutting down maintenance costs in pump houses is to have room around all removable parts or pipe flanges, and access to all grease cups and oil lines. A check chart of oil and grease service points will tend to have the operation done systematically.

The maintenance of sewers in streets and alleys is the duty of the Division of Sewers. Most of the trouble comes from clogged pipes. The source of the trouble may be that of proper joints. The flexible mastic joint is easy to pour and allows a settlement or movement in a pipe but it also allows small roots to start through the compound and in many instances if in the neighborhood of certain trees the entire pipe has been stopped with roots. The small roots grow and crack the pipe allowing larger roots to enter. The use of solid joint materials generally insures a rigid joint and few roots. If the trench has been cut through hard ground the roots follow the back-fill and grow under the pipe and gradually raise and break a pipe and then enter the pipe to clog it up.

An attempt to stop roots from entering the pipe has been made by using copper wire in the cement joints, also the use of cast iron pipe with lead joints in places where the pipe passes under trees or shrubs. Care with the jointing of cast iron and other pipes must be taken. Joints made with moist cement and caulked in place have proved satisfactory on small sewers.

The removal of roots is a problem that takes from one hour to days. In most cases a cutting screw used with flexible rods can accomplish the work. Blue vitriol poured into the roots will kill the roots in some cases. In one instance a pile of roots in a six inch pipe was 6 in. diameter and 30 ft. long and looked like a sea serpent when removed.

Sewer rods are operated in some instances by hand, but new machines capable of turning long lengths of rods are now being used with wonderful success.

The use of a beach ball has proved of considerable advantage in cleaning sewers containing sand. A double scraper pulled between manholes will clean out small rocks and sand. A chain fastened to a windlass or truck may be dragged through the pipe to clean out stones.

All holes in manholes should be plugged tight. A root many feet long and ¾ in. in diameter went through a hole left for a manhole step. Manholes made of concrete should be given a water proof coating outside and inside.

Sewer maintenance could be helped considerably if complete records were kept of all work put in and any changes from the original plans shown on the records. This will require close cooperation between construction crews, maintenance crews, and the engineering department.

The public expects the maintenance crew to immediately eliminate

the trouble so as not to hold up some baby's bath or the head of the family's shower. No matter how efficient the maintenance crew may be if the sewage runs through the front room onto the rugs the property owner will have something to say and many times damage suits can be averted by proper maintenance of the sewage system.

Let us give one cheer and a medal to the man every bit as important as the fireman, policeman or any other public servant—the man who maintains our sewage system and who is seldom seen and from whom we never hear.

DISCUSSION

By Carl M. Hoskinson

Chief Engineer, Division of Water and Sewers, Sacramento, California

The paper by Mr. Phelps on "Maintenance of Sanitary Sewers in San Diego," calls our attention to many interesting although not always pleasant problems which confront the foremen and maintenance crews operating sewer systems.

The City of Sacramento operates a combined sewage disposal system which we believe includes all of the problems of a sanitary system and possibly a few more as solids passing through the sewers may be larger and, therefore, may create more problems for service crews. On the other hand large sewers may be much more easily inspected and cleaned by crews working directly in the sewers.

The area of the City of Sacramento is approximately 14 square miles. The city operates approximately 250 miles of sewers and serves a population of approximately 121,000.

The sewer design and grading comes directly under the city engineer and the operation of sewers and disposal of sewage is handled by the division of water and sewers.

The maintenance crew for the sewer system comprises one foreman and eight laborers. The normal crew for dry weather pumping consists of three pump operators, two helpers, one machinist, and one machinist's helper.

The supervisory personnel of the division of water and sewers comprises superintendent, chief engineer, assistant engineer, and one general foreman, who, in the above order control the operation of the department.

Sewers are usually installed by contractor under the bond plan, and the division of water and sewers makes service connections as necessary.

Sewers of the smaller sizes are of terra cotta pipe with cement joints. Larger sewers are of concrete pipe and of recent years have been of the precast type.

We have experienced the same troubles in maintenance of sewers caused by entrance of tree roots mentioned by Mr. Phelps and have found that flexible sewer rods have been the best means of removing these obstructions which occur for the most part on rights of way

rather than on streets and alleys. During stormy weather the cleaning of storm drains is taken care of by the division of the city into eight districts of which two districts are taken care of by the division of water and sewers, three districts by the street department, two districts by the waste removal department, and one district by the park department. It is the duty of these crews to see that gutter drains are kept open during stormy weather.

The charge for sewer connections to sewer is $3.25. The charge is $2.00 per lineal foot for cutting and replacing pavement and $1.00 per lineal foot in unpaved alleys and streets.

Surely the surest way to make a sanitary department unpopular is to allow odors to arise in sewers, manholes, vent pipes or pumping stations. It is surprising how many odors arising from various sources will be attributed by the irate inhaler thereof to the sewer systems and the one in charge of sewage disposal can expect to be called any time at any place to suppress sewer smells.

In one case we were called late one evening and found the smell was actually drifting across the river from a fire burning on the surface.

Our present disposal is accomplished by pumping into the stream flow of the river and it was necessary three years ago to extend the effluent pipe 270 feet into the stream to prevent deposits of sludge on sand bars which certainly created a nuisance. The disposal of the flow in the current has overcome this difficulty.

The prevention of corrosion of iron and steel in pumping plants has always been a problem where sewer gases are present. We have endeavored to solve this problem by use of coal tar enamels. The use of paints containing lead in sewage plants where sewer gases are present is not advisable as the lead is attacked in a short time by sewer gases.

Copper tubing and copper floats have been found quite successful in connecting up gauges for indication of sewer levels. Screens, fine enough for protection of pumps is desirable but should not be carried to the point where excessive screenings must be otherwise disposed of if the solids passing through the effluent are not limited by other considerations.

The size and shape of objects which may be caught on sewer screens seem to be only limited by the size of the manholes on the system as we have known of construction ladders 8 feet long, whole cases of canned fruit, cats, dogs, and many similar waste products caught on the waste screens. One case causing the greatest furor was a set of false teeth which by chance was mentioned to one of the news reporters who made a humorous story of the incident, but it was taken seriously by no less than a dozen residents who laid claim to their teeth which they claimed to have lost in a wide variety of ways. One man who claimed the teeth thought they belonged to him but that they had become slightly misshapen by passage through their torturous course to the pumping plant.

In another instance paper money was found on the screens and claims for same which were never substantiated were made by many people. At another time a very valuable diamond ring was lost in the

sewer and by quick wit of the foreman it was caught the next morning just below where the house service entered the main sewer. As previously stated, there seems to be no limit except size of inlets to what will be dumped into the sewers and the sewer maintenance crew of any city may never fear being out of a job.

TRAINING OPERATORS OF SEWAGE TREATMENT PLANTS *

By Clarence MacCallum

Consulting Engineer, Mineola, N. Y.

That sewage disposal plants may yield results commensurate with the investment and the needs of the community affected, two major services are required; that of design and that of operation, probably each of equal importance, as a well designed plant suitable for the needs of a particular area with its special problems might fail miserably if improperly operated.

Indifferent operating results usually carry an implication that possibly the design was not all that it should have been, and the designing engineer suffers in reputation although the plant may be the last word in design and construction. This condition has been remedied to some extent by many engineers who stipulate in their contracts that they shall have complete control of the plant during its first year of operation. This usually provides ample opportunity to adjust and modify equipment in the plant so as to obtain designed results.

In the solution of a sewage disposal problem the engineer is naturally the proper person to consider all of the factors and finally produce a suitable set of plans and specifications. The engineer, having had the advantage of technical training and experience, is admirably fitted to undertake his part of the work and in most cases to put into successful operation the fruits of his labor.

Upon completion of construction the plant enters the second stage, that of operation, and even though the designing engineer exercises control for a reasonable period, the operation eventually comes under control of the permanent operating staff.

In the case of large plants, laboratory control usually rests in the hands of technicians who have been especially trained to carry on such work, analyze the results and suggest remedies if any be required. The large plant, however, is the exception rather than the rule, and whereas the large plant due to its numerous staff can employ specialists, the small plant cannot. By far the larger number of disposal plants in New York State are of the smaller type, employing from one to four operators and it thus becomes necessary in the small plant for the operator to cover all of the plant functions including laboratory control tests.

* Presented at Spring Meeting of the New York State Sewage Works Association, Syracuse, N. Y., June 20–21, 1940.

All of these facts have been recognized for some time by engineers, chemists, college faculties and the State Department of Health, and through their combined efforts, laws have been passed for the licensing of operators. Three day, and two week's short courses have been established and much progress has been attained along educational lines.

For an operator, under the present law, to obtain a first or second grade license, it is necessary for him to attend one of the two week's short courses at one of the designated colleges. If, upon completion of the course, he has satisfactorily passed the examination, he is recommended by the college faculty to the State Public Health Council for license in the proper grade.

Operators of public sewage treatment plants are licensed under three grades as set forth in the "Sanitary Code," established by the Public Health Council Chapter XI, Section F, of which Grade III requires a minimum of experience and education. In Grade II, the qualifications are stepped up quite considerably, and, in Grade I, candidates must be college graduates in engineering and have sanitary experience, or have an equivalent combination of education and experience.

With but three rungs in this ladder, they are naturally spaced far apart. In fact, it is not only difficult to reach from rung to rung, but one rung is scarcely visible from the rung below. Perhaps a future rearrangement of these Grades with one added Grade or two, or the reclassification of engineers in Grade I to a new class known as engineer of operation, might provide the solution.

The graduate engineer would seem to have natural advantages to qualify him for the operation of sewage disposal plants provided he has had sufficient experience without the necessity of having to be legislated into a job.

The question also naturally arises, particularly in the case of smaller plants, would a technical graduate find sufficient inducement as a plant operator?

Should a job as sewage disposal operator fail to keep the interest of the graduate engineer, this work must be carried on by practical men with supplementary specialized instruction.

There is also the question as to whether the operation of a sewage disposal plant does not after all involve more practical mechanical genius than a highly technical training.

Regardless of the type or size of the plant, if the operator in charge of it is obtaining first class results, it would seem reasonable to suppose that he should be entitled to some type of first class license. The suggestion has been offered that even under the present law, a man might be licensed as a second class operator capable of taking charge of any plant within the scope and be given in addition, a first class license for the particular plant, or type of plant that he has been successfully operating.

From an educational and training standpoint it might be considered that the designing engineer can take care of himself and perform his

functions in the field of sanitation without special schooling other than that obtained through study of technical literature.

For the operator an entirely different picture presents itself. Swift progress in the technique of sewage disposal has rendered almost obsolete many plants considered excellent only ten, fifteen or twenty years ago. Consequently many of the older operators have been unable to keep pace with the more modern systems and the more complicated methods of laboratory control. Much of the present operating personnel, especially in the smaller plants, was enlisted before the present licensing law became effective with its strict educational prerequisites, such as high school or college diploma.

The establishment of the two week's short courses wherein sewage mathematics, terminology and laboratory technique were given, at first seemed to span the gap, but it soon became evident that a wide diversity of basic education produced some weird results and new methods were sought to augment the two week's course. Entering students varied in education from grammar school sixth grade to Doctors of Philosophy. These differences caused considerable confusion in the college classes as far as pace was concerned and ability to absorb the subject. Examinations indicated that from 20 to 30 per cent passed. It became apparent that a course including mathematics, chemistry and engineering subjects could not be adequately or satisfactorily covered in two weeks unless some preparatory work was done under professional guidance.

It was with this thought in mind that the Long Island Section of the N. Y. S. S. W. A. undertook this spring to conduct a preparatory school to include the subjects covered in more detail in the two week's short courses.

The course was given in eight evening sessions, two of which covered mathematics and terminology, and six of which were laboratory control. Two evenings a week for four weeks during the month of March were scheduled. This provided instruction just prior to the short course period.

Fifty-three different individual operators attended at least one class. The maximum at one session was 44 and the minimum 29. Twelve operators attended all eight sessions, eight others attended seven, seven others attended six, five attended five sessions, one attended four, five attended three, four attended two and eleven attended one session. Twenty-seven attended six or more of the classes.

No final examinations were held as the purpose of the school was for preparation only. Classrooms for the mathematics class were obtained from the village of Freeport and the laboratories for the control work were obtained from the county of Nassau and the New York State Conservation Department without cost.

Members of the Long Island Section volunteered their services as faculty. Messrs. Sweeney, Kelly, Gewecke, Herberger and Reilly who comprised the faculty, thoroughly enjoyed the experience and so ably

conducted the classes as to bring forth a request from the class for a continuation for another month.

Each operator was provided with a Table of Conversion Factors by the Dorr Company, a copy of Sewage Works Operators Guide by F. Wellington Gilcreas, and a copy of Sewage Works Operation by N. H. Wisely and LeRoy W. VanKleek, in addition to mimeographed copies of laboratory test methods and mathematical tables usually used at college short courses. Owing to the size of the classes, it was difficult to provide sufficient space and equipment to permit all of the operators to personally make all of the tests. A full schedule of standard sewage works laboratory tests were carried out by the faculty and a portion of the class, from Imhoff cone tests to bacteriological slides.

That all of those who attended any of the classes benefitted there can be no doubt. The classes also had the effect of exciting a new interest in the operator who attended a school for the first time and created a desire in many to pursue the subject more fully. Some operators completed the course with an awareness of the mathematical, chemical and bacteriological complexity of a material that they had so long looked upon with disdain.

There seems to be little doubt but that a preparatory course such as has just been given on Long Isand, is well worth the effort.

We cannot hope to ever see the time when the small plant will disappear with its attendant shortcomings and handicaps. It therefore behooves every operator to take the fullest advantage of any opportunity to better acquaint himself with the intricacies of sewage plant operation and it may also be suggested that the various state and educational bodies endeavor to provide at reasonable cost, convenient educational facilities to the end that the interest of public health may be better served.

As the schooling of operators involves the use of laboratory control equipment, it is reasonable to assume that any operator who has had the proper schooling and has passed the examination, should keep himself in constant practice by having sufficient laboratory equipment in his own plant laboratory. Gentle agitation on the part of the state authorities and other interested parties might greatly aid the operator in obtaining funds from a reluctant municipality to provide such a laboratory.

As a further suggestion, the curriculum of the present two week's short course may be utilized in an evening course of three nights per week for ten weeks, aggregating 75 class hours; such courses to be held in numerous colleges throughout the state where facilities and faculty permit. Such an arrangement would lend itself more readily to the convenience of the operator, greatly reduce the cost of board and carfare and render unnecessary the possible sacrifice of vacation time to schooling. An arrangement that permits a lapse of a day between classes permits of time to digest the subject more thoroughly and puts the student in a better mental condition to tackle the next day's work.

The funds saved by attendance at a nearby college would permit of

higher tuition fees should financial aid be unattainable from state sources. The present short course of two week's duration, although conducted under the ablest of faculty and with the finest equipment, fails to obtain ideal results due to the concentrated doses of learning of a highly technical subject given in so short a time. Proper mental digestion in the uninitiated apparently cannot proceed at such a pace. Such an alternate course as suggested above might result in a larger number of operators in attendance at short courses, with the strong probability that the two week's courses as now operated would enjoy as great a demand as at present. Many operators might prefer the concentrated dose especially where expense and time are not for their account.

Another question that requires consideration is that of eligibility to attend one of the college courses from which come approval as to the qualification for license. No operator should be denied admittance to the course solely on lack of educational background.

The object of the course is to train men in the particular technique of carrying out with a reasonable degree of accuracy, the laboratory tests required in a sewage plant, to acquaint them with other types of plants, to refresh their minds on the simpler processes of mathematics and to intelligently interpret the results obtained.

The work is largely that of physical procedure and more intimate acquaintance with the tools, instruments, equipment and verbiage, of the laboratory and plant. The operator's own ambition, energy, persistency and aptitude should be the gauge as to whether he takes the course or not.

For centuries mariners have successfully navigated ships on the seven seas, ships valued at millions of dollars carrying cargo and passengers of inestimable value. With the exception of naval officers, very few ship captains have ever seen a campus, let alone attended a university, and yet the art of navigation is based on such deep subjects as astronomy, spherical trigonometry and other technical and mathematical procedures. The average navigator learns the mechanical function of applying prepared tables, formulas, etc., to determine the position of his ship without delving too deeply in to the basic principles of the sciences involved. So must the schools for operators adapt themselves to give the operator that which he requires without attempting to give a complete engineering course.

These comments are offered for the purpose of exciting discussion on the subject of schooling for sewage works operators from which discussion may come new suggestions and new ideas and thereby greater efficiency and more intelligent plant operation.

REPORT ON PRESENTATION OF ANNUAL OPERATOR'S AWARD OF THE NEW YORK STATE SEWAGE WORKS ASSOCIATION *

By C. C. Agar

Chairman of the Rating Committee

This day marks the fifth occasion (the fifth year) of the presentation of an award by the Rating Committee of the New York State Sewage Works Association to the operator submitting the best annual report upon the operation of a sewage treatment plant prepared in accordance with a schedule or outline adopted by this association. This is a contest for operators of plants large and small in size, simple or complex in design and high or low in degree of treatment, with all reports graded and rated on the same basis of conformity with the requirements of the rating schedule, clarity of presentation and the correctness or credibility of the data submitted.

One of the prime objectives in the preparation and submission of annual reports is improvement in the standards of plant operation throughout the state. And along with this is the stimulation afforded for the collection of essential data on plant operation in a standardized form which is not only convenient but can also be readily interpreted by members of the sewage works fraternity. The reports therefore become a distinct contribution to the advancement of the art of sewage treatment. Furthermore, the operator profits not only from the experience gained but also through the recognition given him at this meeting and the letters of commendation transmitted to his superiors. Lastly, the municipality or other agency owning the plant obtains the benefit of a complete record and analysis of plant operation which can be valuable in many ways.

This year is unique in the records of the Rating Committee of the Association for several reasons. First the number of operators submitting reports this year was far greater than in any previous year, there being a total of 22 such reports including four submitted by previous winners of the award, giving a net total of 18 reports eligible for consideration in selecting the 1940 award. It is significant that previous winners continue to recognize the value of preparing an annual summary of plant operation and submit copies of the same to the committee with full knowledge that they cannot again secure the prized cup. The committee greatly appreciates this continuing record of accomplishment and work well done.

Secondly, the year is marked by the outstanding excellence and near perfection of a large number of the reports submitted. In fact the work of the committee in selecting the prize report was made more difficult and exacting by the fact that there were several reports with ratings separated only by a few per cent or fractions of a per cent in the

* Presented at the Spring Meeting of the New York State Sewage Works Association, Syracuse, N. Y., June 20–21, 1940.

final summary. Seven of the reports were rated at over 90 per cent with many more in the upper eighties.

Thirdly, this year is the first time that an operator of a state institutional plant has received this signal honor. He has submitted a report for several years, persisting and continually improving his work. Last year he was the runner-up and this year attained the enviable goal which is all the more creditable in the fact of the unusually keen competition.

Before announcing the winner and presenting the award I want to pay tribute at this time and afford recognition and appreciation of the association to all the operators who took part in this activity this year. The following operators (listed alphabetically) submitted reports for the year 1939:

*1. C. George Andersen, Rockville Centre
2. S. P. Anderson—L. A. Sammis, Pilgrim State Hospital, Brentwood
3. William D. Denise, Greece Sewer District
4. William Edwards, Gowanda State Hospital, Helmuth, N. Y.
5. Arnold H. Hale, Brighton Sewer Dist. No. 2
*6. H. O. Johnson, Belgrave Sewer Dist., Great Neck
7. Henry Lambert, Batavia
8. James T. Lynch—H. E. Milliken, Auburn
9. Frank Marx, Highland Sewer Dist.
10. George Mathers, Garden City
11. Charles W. McBreen, Rockland State Hospital, Orangeburg, N. Y.
*12. E. A. Marshall (Reports on 2 plants), Geneva
13. Joseph F. Reardon, N. Y. State Reconstruction Home, West Haverstraw
14. Joseph E. Rehler, Olean
15. Glenn Searls, Rochester
16. Edward J. Smith, Niagara Falls
17. Otto Thomasett, J. N. Adams Memorial Hosp., Perrysburg
18. E. J. VanDeusen, Malone
19. Arthur H. Woefle, Dunkirk
20. Braman E. Zeitler, Pittsford

And now on behalf of the Rating Committee and the members of the New York State Sewage Works Association, I have the honor to present this loving cup to the operator who has obtained the highest rating of operating reports for the year 1939. Mr. Reginald A. Murphy, operator of the treatment plant at the Willard State Hospital, it gives me pleasure to give this cup, a symbol of high achievement, to you at this time. It reflects honor upon your institution and its officials and may it serve as a continued inspiration to you in your work and in doing your part in advancing the science of sewage treatment.

* Previous winner of award.

WILLARD STATE HOSPITAL TREATMENT PLANT, WILLARD, NEW YORK

By Reginald A. Murphy, Operator

The Willard State Hospital is located in the Finger Lakes region on the east side of Seneca Lake, from which it receives its water supply. Until the present sewage plant was built, the hospital discharged its sewage through primary and secondary treatment until part of the plant was damaged by flood. The new sewage treatment plant was completed in September, 1936, at a cost of $110,000.

The sewage treatment processes are as follows: One mechanically cleaned coarse bar screen, two rectangular mechanically cleaned sedimentation tanks, three dosing tanks, three sprinkling filters, one plain secondary sedimentation tank that also serves as a chlorine contact tank, one Bailey recorder for measuring sewage flow and a complete chlorinating plant having two Wallace and Tiernan vacuum chlorinators. The secondary sedimentation tank effluent flows into Seneca Lake.

Sludge treatment and accessory processes comprise two 45 gallons-per-minute Marlow sludge pumps, one Wallace and Tiernan lime feeder, two heated sludge digesting tanks with mechanical agitators, one gas fired boiler with a combination flame trap, one fuel oil burner, one hot water circulating pump and meter, one hot water temperature control valve and two glass covered sludge drying beds with chain hoist carrier for use in removing dried sludge from beds to truck.

The sewage from all of the buildings at the institution, with the exception of two, flows to and through the plant by gravity. A booster station equipped with two float control centrifugal pumps lifts the sewage from the two buildings referred to above into the gravity trunk sewer.

The plant was placed in operation August 1, 1936, and was designed for a population of 4,000 and a sewage flow of 800,000 gallons per day, having primary and secondary treatment.

This plant serves the State Hospital only. The present population is 3,600, obtained from daily census records of institution.

Separate sewers are used and there are no storm water diversion outlets or by-passes. There are no industrial wastes.

The sewage flow is measured by a float type Bailey recording meter over a 90 degree V-notched weir, in the effluent line from the secondary sedimentation tank.

The purpose of the treatment is to protect the hospital water supply taken from the lake, to protect fish life, and to avoid a nuisance condition along the hospital bathing beach.

The average daily flow for the year 1939 was 590,808 gal. with an average maximum daily flow of 702,640 gal. and an average minimum daily flow of 495,090 gallons.

Operating Data and Practical Control Tests

Coarse screens: One single unit automatically cleaned bar screen. The screen is three feet wide and four feet in height, and set 30 degrees to the vertical. Bars are made of three-eighths inch steel and spaced one inch apart. The screenings are removed every 25 minutes by an automatic rake operated by a time clock. The total cubic feet of screenings removed for the year 1939 was 1,274.5 cu. ft., with an average of 106.2 cu. ft. per month.

The screenings are dumped on a draining platform from the bar screen where they are allowed to drain. They are then removed three times daily and placed in a galvanized iron can and hauled a short distance from the plant and covered with six to eight inches of air-dried sludge.

Primary sedimentation (Mechanically equipped): There are two single straight line type settling tanks with flat bottoms, having a sludge hopper in the influent end, and an automatic scum remover in the effluent end. Each tank is equipped with a Link-Belt type mechanism for continuous sludge collecting and tank skimming. Each tank has a capacity of 32,500 gallons. The detention period, based on the average sewage flow, was 2.64 hours.

The sludge collecting mechanism is operated twice daily for a period of one hour, being placed in operation twenty minutes before the sludge is pumped from the hopper. Sludge is withdrawn to digesters twice daily. There were 42,915 cu. ft. of sludge withdrawn during the year 1939. The average amount of sludge withdrawn per month was 3,576 cu. ft.

The scum is removed from the sedimentation tanks by an automatic scum remover and collected in the scum trough. The scum is pumped direct to digesters once daily. We have no means of accurately measuring the volume removed. Approximately 190 cubic feet are removed during the year, or 0.09 cu. ft. per million gallons.

Settleable solids in influent are run daily. The average for the year was 5.25 c.c. This determination is also made on the effluent at least once a day and the average for the year, 1939, was 0.21 c.c.

Dosing device: Three single-unit dosing tanks having a total capacity of 10,000 gallons. Each dosing tank has a separate weir, and the weirs are set for each tank to receive the amount of sewage in proportion to the filter bed upon which it empties. Being of different capacity, the tanks do not all fill or discharge at the same time.

The dosing tanks are cleaned once each week by scraping the grease from the side walls and washing them with a stream of water from a fire hose.

Trickling filters: There are three separate units of the sprinkling filter type.

Sewage is distributed to the filter beds by the fixed-type distributors and sprayed by 120 "D" type nozzles.

Area of Filters	Depth of Filters	Size of Crushed Stone	No. of Distributors Lines	No. of Nozzles
4,910 sq. ft.	6 ft.	1½" diam.	6	30
5,850 sq. ft.	6 ft.	1½" diam.	6	36
7,780 sq. ft.	6 ft.	1" diam.	10	54
Total area				18,540 sq. ft.

Distributors are cleaned once each month by removing the nozzles on the end of each line for a short period and allowing the sewage to flush out any foreign material. The nozzles are cleaned whenever they become plugged, or when they do not have a full spray. A total of 234 nozzles were plugged during the year, of which 162 were caused by leaves in the fall of the year. An average of 19 nozzles were cleaned per month.

We have had no objectionable odors or filter flies.

The settleable solids in trickling filter effluent averaged 0.44 c.c. for the year, 1939.

Relative stability of trickling filter effluent (Methylene blue test) was 14 days.

Secondary Sedimentation (plain tank): One single-unit rectangular tank with eight evenly divided V-shaped hoppers in bottom, having a total capacity of 27,646 gallons. The detention period, based on the average sewage flow, was 1.1 hours.

Sludge is pumped from the eight hoppers in the sedimentation tank twice each month during the warm weather, and once each month during cold weather.

Sludge was pumped to the digestion tanks during January, February, and March. For the remaining nine months, sludge was pumped to drying beds.

The settleable solids in secondary tank effluent averaged 0.18 c.c. for the year 1939.

No stability tests were taken as the effluent was chlorinated.

Chlorination: We have two Wallace and Tiernan vacuum chlorinators. Pre-chlorination is applied to the raw sewage at the influent end of the primary sedimentation tanks for odor control. Post-chlorination is applied to the influent end of the secondary sedimentation tank for bacteria control.

We used a total of 8,043 lb. for post-chlorination and 126 lb. for pre-chlorination or an average of 38 lb. per million gallons.

The contact period for pre-chlorination was 2.64 hours and for post-chlorination, 1.1 hours.

Our average daily reading for residual chlorine was 0.5 part per million.

No *B. coli* tests were taken.

Sludge Digestion Tanks: The plant is provided with two single-stage heated digesters of the fixed cover type, 26 ft. in diameter and 15 ft. side wall depth, having a total capacity of 16,000 cubic feet. They are

equipped with a Hardinge type agitator for the stirring of sludge in the bottom and for breaking any scum formation in the top. A scum line is installed in both digesters for the removal of scum if it becomes too thick. Four sludge sampling valves are installed, 3, 6, 9, and 12 ft. from the bottom of both digesters. Three hot water coils of one inch wrought iron pipe are suspended in both tanks one foot six in. from the bottom and spaced three ft. apart. The roof of the digesters slopes upward one-fourth inch per foot to the center where sludge gas is collected by a water seal gas dome. The gas is carried by a one and one-half in. wrought iron pipe to the control building where a combination flame trap, a gas meter, and a gas-fired boiler are installed.

Digestion capacity actually used, based on average liquid level in tanks, is fifty per cent.

The average digestion temperature for year, 1939, was 76° F. The average pH of the sludge was 6.9. A total of 700 lb. of hydrated lime was used during the year.

The total volume of sludge removed from the digesters was 4,711 cu. ft.

When pumping raw sludge to the digesting tanks, the supernatant liquor is forced out over the overflows and returns to the primary sedimentation tanks.

Sludge Drying Beds: There are two sludge drying beds of the standard green house type with ventilators in top and sides, one is a two-section drying bed with an area of 1,200 sq. ft.; the other a four-section drying bed with an area of 2,800 sq. ft. The beds consist of six in. of sand on one foot of crushed stone underdrained by four in. of tile in the center of the beds.

The average depth of wet sludge on beds drawn from digesters was nine and one-half inches. The average depth of wet sludge on beds drawn from secondary sedimentation tank was three inches.

The average drying time of sludge drawn from the digesters was 30 days and that from the secondary tank, 35 days.

No chemicals were used to condition sludge.

All sludge is measured by the depth drawn on beds.

The total volume of wet sludge applied to beds from digesters was 4,711 cu. ft.

The total volume of wet sludge applied to beds from secondary tank was 1,218 cu. ft.

The total volume of air dried sludge removed from bed drawn from digesters was 1,699 cu. ft.

The total volume of air dried sludge removed from bed drawn from secondary tank was 820 cu. ft.

Sludge bed drainage is collected by a four inch under-draining tile and flows to the secondary sedimentation tank.

Sludge is removed from beds by forks and placed in a chain hoist carrier and emptied into truck. The sludge is then used to cover the screenings removed daily.

Sludge Analyses: The laboratory is equipped with the following

equipment; a 500 gram balance, water bath, drying oven, desiccator, centrifuge, comparator, nickel evaporating dishes, graduated cylinders, gas burner, gasoline burner, electric heater, and all the necessary glassware and chemicals.

The raw sludge in the sedimentation tanks is sampled by means of a pitcher pump installed in the influent end of the tank and extending to within eight inches from bottom of sludge hopper. Samples are taken daily to determine the time required for the removal of sludge and are analyzed once each month.

Sludge is sampled twice each month from four two-inch sampling valves in the digesting tanks installed 3, 6, 9, and 12 feet from bottom of tanks. Samples are taken to determine the sludge depth and are analyzed for total and volatile solids. Sludge from the secondary sedimentation tank is sampled and analyzed when being withdrawn.

Samples of air dried sludge are taken as sludge is removed from beds and are analyzed.

Average for year of dry solids percentage in sludge:

Primary Sludge	*Digested Sludge*	*Air Dried*	*Secondary Sludge*
2.0%	7.23%	40%	1.5%

Average pounds (dry basis) of raw sludge solids per million gallons of sewage treated annually was 250.83.

Average pounds (dry basis) of digested sludge solids per million gallons of sewage treated annually: Primary treatment, 118.31 lb.; secondary treatment, 7.37 lb.; Total, 125.68 lb.

Average pounds per capita daily of raw solids recovered as sludge was .041.

Gas Collection: Each digester is equipped with a gas dome for the collection of sludge gas and is sealed by twelve inches of water for relief in case of excess pressure or stoppage in gas lines. The gas flows through a one and one-half inch wrought iron pipe to the control building where a combination flame trap, gas meter, and gas boiler are installed. Excess gas is burned in a waste gas burner located fifty feet from the control building.

The total volume of gas produced was 1,218,206 cu. ft. or an average daily volume of 3,337 cu. ft.

Gas Utilization: Gas is burned in a gas fired boiler to heat digesting tanks, control building, and screen and chlorine room.

We have one Bryant tubular gas fired boiler rated at 180,000 B.T.U. per hour.

No meter is installed to measure the amount of gas used in the gas fired boiler. All the gas produced is measured by one meter. Above a pressure of six inches, the excess gas is burned in a waste gas burner.

Cost Data: The original cost of the treatment plant was $110,000. The total maintenance and operating cost for the year 1939 was $2,527. The average cost per million gallons of sewage treated was $11.72 or $0.71 per capita.

Editorial

THE FEDERATION MUST PROGRESS

So much has been written about the reorganization of the Sewage Works Federation that it seems unnecessary to review the events that led up to the present intention to have an open discussion of the plans at the Chicago Convention, scheduled for 10 A.M. Saturday morning, October fifth. Mr. Emerson will preside and expressions of opinion will be welcomed from members of the Federation, particularly those who represent one of the twenty-five member associations. Chairman Emerson will have to bar aimless or uninformed discussion, in order to keep the issues clear and to accomplish constructive results. No final nor binding action can be taken at the Chicago meeting, because the official reorganization will have to be accomplished at the next annual meeting of the Board of Control, in January, 1941. However, the discussion at Chicago ought to clarify the muddy waters of doubt and suspicion that have arisen in some places regarding the motives and intentions of the Reorganization Committee.

By far the majority of the members of the present Federation realize that a turning-point has been reached in its affairs. We can no longer stand still and refuse to accept the further responsibilities of time and money that are required to advance the prestige of the Federation. We need more activities, more cohesive strength on committee work, unity on national policies, a clearing house for sewage works information, aid for the poorly paid operators of small sewage works, publication of manuals and data on costs, more frequent publication of the Journal, and an annual Convention that will bring together sewage works men from all over the country, in the one organization to which they should belong. Now we find them at conventions of the American Water Works Association, the American Public Health Association, the American Society of Civil Engineers, the American Chemical Society, the American Public Works Association, and others. In all of these the sewage men are only participants—why don't we draw our own family together in our own sewage works convention? Well, the answer is—we will—and the Chicago Convention ought to develop only one regret—that we haven't had a national convention years ago.

Now as to the Water and Sewage Works Manufacturers' Association, and their place in the picture, even some loyal and sincere members of the Sewage Works Federation have suspected that the Manufacturers' Association is trying to dictate the future of the Federation, and to run it to their profit and advantage. This suspicion is unjust if one cares to find out how the manufacturers handle cost of exhibits and expenses of conventions. The cost of exhibit space to manufacturers is adjusted so that there will be sufficient funds turned over to

the Convention Committee to assure a successful meeting ($1500 in the case of the Chicago Convention), but at the same time to hold down the cost of exhibits to the manufacturers, so that they will not be charged excessive or variable rates by exhibit committees of successive conventions. The Manufacturers' Association have competent and experienced men to handle exhibits and such liaison officers are needed to assure a successful convention.

The proposals for reorganization recognize that there must be some increase in dues, but after long debate on this subject, Mr. Emerson's committee has prepared a compromise schedule of dues which gives a lower rate for the operator of a small plant, or others who, in the judgment of officers of local associations, are entitled to a reduction. The rates will be discussed at Chicago, and the schedule adopted by the Board of Control in January.

Mr. Emerson writes to the Committee that "all whom I have contacted agree that our basic organization as separate associations should not be disturbed; that added income for the Federation is necessary, particularly if it is to expand its activities; and finally, that a more closely organized Board of Control and greater freedom in selection of officers, committee chairmen and committee members is desirable."

So much sincere effort has gone into the preparation of constructive plans for consideration at the Chicago meeting that it would be deplorable if members or representatives of local associations come with minds fixed against the new plans. Let's rally round the new plans and solve any minor difficulties by tolerance and a spirit of compromise.

F. W. MOHLMAN

GEORGE B. GASCOIGNE

Most of our readers have heard of the sudden death of George B. Gascoigne in Cleveland, August seventeenth. Although he had not been in his former good health for some time, his death was a shock to his friends and co-workers.

Mr. Gascoigne was only 55 years old and almost at the zenith of his career as a consulting engineer. He had designed many large sewage works, including the plants in Cleveland, and was engaged to prepare plans for Philadelphia. His office at Cleveland has been expanding ever since it was opened in 1922, and in 1936 he established another office in New York, under the name of Gascoigne and Associates. C. A. Emerson, Jr., has been in charge of this office.

George Gascoigne was prominent not only in a technical way but also because of his pleasant and genial personality and his magnetic ability to attract and hold friends. He will be sadly missed at the conventions where he was always to be found. It is hard to realize that he is gone.

F. W. M.

Proceedings of Local Associations

ARIZONA SEWAGE AND WATER WORKS ASSOCIATION

Fourteenth Annual Meeting

Tucson, Arizona, April 19–21, 1940

On April 19, 20, and 21, the Arizona Sewage and Water Works Association held their Fourteenth Annual Meeting in Tucson, with headquarters at the Santa Rita Hotel. Sixty-five members were registered.

The business meeting was opened on the morning of April 19 by Phil J. Martin, Jr., President of the Association. After a few words of greeting the order of business was declared as follows:

The secretary's report was read and approved.

The Treasurer's report showed a balance of $89.20 in the checking account.

John A. Carollo and A. L. Frick, Jr., members of the Board of Control presented and discussed formation of a National Sewage Works Association. It was moved by Richard Bennett and seconded that the Association would not take an active part in the formation of a National Sewage Works Association. This motion was carried unanimously.

Report of Operators Registration Committee was read by Charles W. Hircock, chairman of this committee.

It was moved by Charles Hircock to appoint a Registration Committee on a permanent basis. This was passed without discussion.

The report of the committee on Constitution and By-Laws was presented by A. W. Miller, chairman. It was moved by A. W. Miller and seconded by Richard Bennett that the Constitution as presented should be accepted by the organization. After some discussion by A. L. Frick, Jr., Dario Travini, Phil J. Martin, Jr., the Constitution was accepted unanimously.

The report of the Program Committee was presented by Richard Bennett. It was moved by A. L. Frick, Jr., and seconded by John A. Carollo that the program committee be given a vote of thanks for the programs.

The report of the Nominating Committee was handed to the secretary for reading, by the president, Phil J. Martin, Jr. It was moved by Richard Bennett and seconded by Dario Travini that the report of the nominating committee be accepted and that the secretary be instructed to cast a unanimous ballot for the nominees presented. This was passed unanimously. The officers for the 1940 to 1941 term are listed as follows.

A. W. Miller, Phoenix, *President*
G. A. Rhoads, Safford, *First Vice-President*
Geo. W. Seeley, Tucson, *Second Vice-President*
F. C. Roberts, Jr., Phoenix, *Secretary-Treasurer*

Board of Directors

A. L. Frick, Jr., 1 year, Los Angeles, Cal.
Phil J. Martin, Jr., retiring president 2 years, Tucson
Robert W. Cushing, 1 year, Holbrook
Dave Ostrander, 1 year, Holbrook
J. P. Sexton, 1 year, Casa Grande
Bernard Schiller, 1 year, Yuma

Under the heading of old business, G. A. Rhoads of Safford extended a third invitation from Safford to hold the Fall Meeting in this town.

Bernard Schiller of Yuma presented a written invitation from the Yuma Chamber of Commerce for the Fall Meeting to be held in Yuma.

Upon presentation of these two invitations, it was moved by J. P. Sexton that a ballot be taken to guide the Executive Committee in the selection of the next meeting place. This was seconded by A. L. Frick, Jr., and passed unanimously. A ballot was collected, and upon survey it was found that the ballot was 19 in favor of Safford and 14 in favor of Yuma.

A discussion insofar as the spring meeting was concerned was introduced by Dario Travini and engaged in by Richard Bennett, Phil Martin, Jr., A. L. Frick, Jr., and F. C. Roberts, Jr. This discussion was closed by the decision to abide by the new constitution to allow the selection of the next meeting place to be made at the fall meeting.

At the informal dinner meeting in the evening of April 19, Phil J. Martin, Jr., presided with John A. Carollo as toastmaster. At this meeting the association was entertained by a series of dancers presented by Harry Blackledge. This was followed by a talk presented by Robert Benzie, water and fuel supervisor S. P. Ry. Co., retired, Tucson, Arizona. This was followed by a short talk by J. D. Dunshee, acting superintendent of state health office, Arizona State Board of Health, and by Professor E. S. Borgquist, Professor of Civil Engineering, University of Arizona, Tucson. The association was entertained by a slight of hand performance by one of the members, J. B. Saunders of the Home Realty Company of Tucson.

Round table discussions conducted by A. M. Rawn on the papers discussed during the day followed the technical sessions on April 20.

At the evening meeting Alden W. Miller acted as toastmaster. A skit, songs, and dancing were the order of business following the meal.

On Sunday, April 21, the group met in front of the Santa Rita Hotel and then drove in a caravan of eleven cars to the north side elevated tank, to the north side pumping station, to the south side elevated tank, to the south side booster plant and to the Tucson Water Department to watch a demonstration of water main cleaning, provided through the

courtesy of the Flexible Underground Cleaning Company of Los Angeles, and the Sparling Meter Company of Los Angeles. Following the demonstration which was declared to be quite successful, the group then went to the Tucson Sewage Disposal Plant where an inspection was made of the facilities.

The papers devoted to sewage work at this meeting were as follows:

"Why the *B. Coli* Group?" Robert A. Greene, PHD., Director, Arizona State Laboratory, Tucson.

The history of the bacterial examination of water was outlined. It is not possible to test waters for the pathogenic organisms that might be present. An indicator organism was decided upon. There are more than 30 species of *B. Coli,* the indicator organism. *B. Coli* species may be found outside of the intestinal tract of man. *B. Coli* is found in intestinal of warm blooded animals. Other organisms have much the same characteristics as *B. Coli.* Notwithstanding it is the best test for potability of water that is known. *B. Coli* or *Eschericia Coli* is capable of fermenting lactose with the production of acid, gas, or both; it is rod shaped; non-spore forming; gram negative. Our laboratory reports the presence or absence of the group without attempt to separate into fecal and non-fecal types. If we are in error it is on the side of safety. The maintenance of a good water supply depends on the cooperative efforts of operators, engineers, health officers, laboratory, to say nothing of the consumer.

"Stray Current Electrolysis, Its Causes and Methods of Prevention," Robert R. Ashline, Electrolysis Engineer, Los Angeles Bureau of Water and Power.

The corrosion of underground structures may be divided into two classes by stray currents, and soil corrosion. The stray current electrolysis is almost universally caused by electric railway systems which use direct current for their power. Areas that pick up current do not worry us, it is where the current leaves the pipe that metal is carried away. Rail sizes of railway have not been increased to accommodate new loads, so part of the current is carried in water pipes; aggravated by poor rail bonds. Utility companies have not protected pipe with adequate coatings; nor formed good bonds between lengths of pipe to provide adequate drainage of stray currents. Cooperative drainage of stray currents of all utilities has assisted in the solution of the problem, Back filling, coating of pipe, and increase of railway sizes have assisted in the solution of the problem.

"Flow Measurements of Water and Sewage," Lee H. Chamberlain, Mgr., Water Works Sales, Crane Company, Chicago.

The types of devices for measuring flowing water are outlined in two tables, showing the application of various measuring devices such as weirs, Venturi tubes, Venturi flumes, orifice plates, and pitot tubes.

The variation in head for 10 to 1 flows, places the triangular weir in a position of advantage, with Venturi flumes, rectangular and cippolettie weirs, as next; orifice plates, pitot tubes and Venturi tubes and flow nozzles last.

A study of the loss of head through the various devices is made with the pitot tube as causing the smallest loss, submerged Venturi flume, Venturi tube, flow nozzle, Venturi free-flowing flume, orifice plate, and weirs as causing varying degrees of losses from low to high as listed. The presence of sewage solids alters the conditions, placing the Venturi flume in a position of advantage as far as sewage works practice is concerned.

"Wilcox Sewerage System," Robt. M. Cushing, Headman, Ferguson and Carollo Engineers.

This paper presented a description of the new Willcox Sewerage System, showing construction difficulties and other difficulties facing the consultant and contractor.

"Biofiltration Sewage Treatment Process," Earl M. Kelly, Western Manager, The Dorr Co., Los Angeles.

The study and application of the biofiltration process was presented in a number of slides that illustrated the various installations made. Studies of the success of this type of process were compared with other processes. The process may be installed with exceedingly wide variations, to produce wide variations in the type of effluent desired. The process is exceedingly flexible to meet a wide variation of local conditions.

"Comminution of Sewage Disposal Plant Screenings," Phil F. Morgan, Sanitary Engineer, Chicago Pump Company, Chicago, Illinois.

The disposal of the screenings from a plant is a considerable problem. Smaller plants usually bury the screenings, larger plants incinerate them. By altering the form of the solids they may be treated with the rest of the sludge. Comminutors have slot widths from 3/16 in. to 3/8 in. Teeth and shear bard are cast stellite. Mechanisms require weekly lubrication and inspection of cutting surfaces. Lower teeth may have to be resharpened at monthly to two yearly intervals depending on amount of grit in the sewage. Top teeth experience small wear. A seven inch size comminutor takes flow to 350,000 G.P.D.; a 36 in. drum takes a flow of 25,000,000 G.P.D. Cast iron bases supplied with small units. Structures are arranged for power cut-offs, and varying flows for power economies. Machines must be installed to prevent deposition of solids, and carrying velocities. Machines must be designed to fit the job, and with proper maintenance will handle all conditions.

"Sanitary Practices as They Are Influenced by War," A. M. Rawn, Asst., Chief Engineer, Los Angeles County Sanitary Districts, Los Angeles, California.

The practices of the European powers in the conservation of sewage for the irrigation of crops is dictated by heads of governments, without respect to engineering judgments. Storage of coal in trickling filters affords future source of heat and power. Plant cases used for propelling automobiles. Concentrations of populations on small towns place unpredictable loads on disposal units as well as water facilities. Sanitation of air-raided retreats is a major health problem, calling for pumps and unusual sanitation.

Private facilities. Placement and protection of water and sewage plant facilities of major concern to best serve populations. American sewage practices are far in advance of European and particularly Egyptian practices. Foreign practices indicate that they are not focusing attention on American advances.

"Sewerage Service Lines Between the Home and the Lateral Sewer," George W. Seeley, City Manager and Engineer, City of Tucson, Arizona.

A house connection service should maintain a minimum grade of ¼ in. per foot, with cleanouts at 45 deg. bends. Vitrified clay or cast iron pipe are recommended. Each residence should have a separate connection. G. K. compound is the only one that has been found to keep roots out of vitrified clay tile. Minimum sizes of line are 4 in. The connection should enter the pipe in the upper 180 degrees of the pipe. No fitting is allowed to protrude into the lateral sewer. The main sewer connection is the only concrete one on the job, and is generously enclosed in concrete.

F. C. Roberts, Jr., *Secretary*

MICHIGAN SEWAGE WORKS ASSOCIATION

Sectional Meeting

Jackson, Michigan, July 25, 1940

Through the courtesy of President A. B. Cameron, superintendent of sewage treatment plant, Jackson, Michigan, some 49 members of the Michigan Sewage Works Association and their wives met in the first regional meeting for 1940, at a luncheon in the Hotel Otsego. Following a gracious welcoming by City Manager Ismun, President Cameron introduced Col. Edward D. Rich, recently retired director of the Bureau of Engineering, Michigan Department of Health, and Mr. John M. Hepler, successor to Col. Rich. Through their years of service with the State Department of Health, both of these gentlemen were well known to most of the operators present and the gathering felt very happy to have them present.

A program of entertainment for the ladies was provided which included an inspection trip through the State Prison of Southern Michigan which is located near Jackson. To date, we have not been informed of any missing sewage plant operators' wives so they must have all successfully passed muster at the gate on the way out.

At the business meeting several items of particular interest to the membership were discussed. It was the consensus of opinion of those present that the Michigan Association should be represented at the coming national meeting to be held in Chicago. Mr. Hepler indicated that a member of his staff would be delegated to attend this meeting and it was voted that said member be officially named to represent the Michigan Association with the cooperation and support of such other members as find it possible to attend.

Following a discussion of the subject, it was voted to extend an invitation to the wives and daughters of the membership to attend the next annual meeting and the program committee, to be named by the president, will be asked to provide a suitable program for their entertainment.

The matter of suitable entertainment at the annual meeting and the general social features thereof was discussed at length and finally voted to have the program committee designated to make suitable arrangements for entertainment.

President Cameron in behalf of Mr. N. G. Damoose, who was unable to attend, introduced a resolution on the retirement of Col. Rich which was unanimously adopted.

Be It Hereby Resolved, that we extend our sincere gratitude, our deep appreciation and our profound respect to Col. Edward D. Rich, a loyal public servant. We pridefully proclaim our profound affection and great admiration for Colonel Rich, a gentleman of dignity and sterling character and inimitable personal attributes. To such a man, then, we pay homage and tribute and wish for this great and true friend the fullest measure of good health and happiness to Col. Rich. Further, that copies of this resolution be sent to His Excellency, the Governor of the State of Michigan, the Honorable Luren D. Dickinson and Dr. H. Allen Moyer, Commissioner of Health.

By: The Michigan Sewage Works Operators Association

Upon completion of the matters of business before the meeting, President Cameron asked Mr. Jackson to describe briefly the landscaping project at the sewage treatment works. Mr. Jackson responded by describing what had been done outlining the type of planting, the methods of procedure, magnitude of the work and certain technical details involved in the construction and maintenance of the plant grounds. The meeting then adjourned to the Jackson treatment plant and inspected the grounds described.

It appears from the success of this meeting that additional regional meetings are definitely in order and undoubtedly more of such meetings will be held.

W. F. Shephard, *Secretary*

PACIFIC NORTHWEST SEWAGE WORKS ASSOCIATION

Sixth Annual Meeting

Portland, Oregon, May 7, 1940

The Sixth Annual Meeting of the Pacific Northwest Sewage Works Association was held on Wednesday, May 7, 1940, at the Portland Hotel, in Portland, Oregon. Ninety-seven men registered for the convention. Mr. W. P. Hughes, City Engineer, Lewiston, Idaho, Chairman of the Association, presided.

The morning program opened with a Report of the Committee on Sewer Pipe Joints and Infiltration given by C. M. Howard, Seattle, Washington, Chairman. Ben S. Morrow, City Engineer, Portland, Oregon, then told about "The Proposed Portland Sewage Disposal Project," which was followed by a discussion by M. L. Franzen, City Manager, Oregon City.

A Symposium on "Water Pollution Control" was a very interesting feature. V. G. Lamoureux, P. A. sanitary engineer, U. S. Public Health Service talked on "The Program of the U. S. Public Health Service for the Control of Water Pollution in the Ohio River Basin." "Progress in the Reduction and Prevention of Water Pollution in the Pacific Northwest during 1939–40" was discussed by Roy M. Harris, W. V. Leonard, Carl E. Green, State sanitary engineers, respectively of Washington, Idaho, and Oregon. Marshall N. Dana, editor, Oregon Daily Journal, Portland, brought the symposium to a close by a talk on "The Need for the Reduction and Prevention of Water Pollution in the Pacific Northwest."

"Financing Sewerage System and Sewage Treatment Plant Construction and Operation in Oregon by service charges" was ably given by C. M. Everts, Jr., assistant sanitary engineer, Portland.

During the luncheon hour in the Grill Room of the Hotel, colored pictures of sewage treatment plants were shown by R. E. Koon, consulting engineer, of Portland, Oregon.

The afternoon session opened with a Round Table Discussion on "Sewage Treatment Plant Operation Troubles," this was participated in by T. E. Johnson, sewage treatment plant operator, Yakima, Washington; James Burns, sewage treatment plant operator, Hillsboro, Oregon, and John R. Hill of Moscow, Idaho. Paul C. Ward and H. C. Clare, both from the Idaho State Department of Health, talked interestingly on this subject.

The following papers were presented:

"The Time and Expense Involved in the Operation of Small Sewage Treatment Plants," by C. L. Barthlow, water superintendent, Zillah, Washington, and R. M. Lowe, water superintendent, Burns, Oregon.

"Sewage Pumping Equipment and Its Maintenance," by W. P. McNamara, sewer engineer, Seattle, Washington.

"Metals and Paints for Sewage Pumping Stations and Treatment Plants," by L. R. Stockman, consulting engineer, Baker, Oregon.

"Sewage Treatment Plant Operators' Short School, 1940," by Fred Merryfield, associate professor of civil engineering, Oregon State College, Corvallis, Oregon.

A report on the Annual Meeting of Federation of Sewage Works Associations held in New York, in February, was given by Professor Charles Mockmore, Oregon State College, Corvallis, Oregon.

The following officers were elected for the year 1940–41:

President—A. D. Butler, City Engineer, Spokane, Washington.
First Vice-President—C. D. Forsbeck, City Engineer, Tacoma, Washington.
Second Vice-President—R. E. Koon, Construction Engineer, Portland, Oregon.
Secretary-Treasurer—Fred Merryfield, Oregon State College, Corvallis, Oregon.

CECILE SMITH, *Secretary*

MARYLAND–DELAWARE WATER AND SEWERAGE ASSOCIATION

Fourteenth Annual Conference

Salisbury, Maryland, May 16–17, 1940

The Fourteenth Annual Conference of the Maryland-Delaware Water and Sewerage Association was held at the Wicomico Hotel, Salisbury, Maryland, on May 16 and 17, 1940. One hundred and twenty-six members and guests were registered.

The Conference opened with a cordial address of welcome by the Honorable A. W. Boyce, Mayor of Salisbury.

With President A. M. Tawney, presiding, the technical sessions began with the presentation of a paper entitled "The Need for Disinfection of Ground Water Supplies" by George L. Hall, chief engineer, Maryland State Department of Health.

Dr. A. J. Fischer, Sanitary Development Engineer, The Dorr Company, read a paper entitled "The Biofiltration System as a Means of Varying the Degree of Sewage Treatment" in which he discussed basic considerations with regard to the operation of this high-rate process. In his discussion, F. S. Friel, Albright and Friel, Inc., Consulting Engineers, emphasized the variation in degree of treatment possible when biofiltration is used and discussed the effects of temperature on filter performance. He added that increased digestion capacity appears necessary at biofiltration plants due to lack of digestion in the filter itself and increases in the moisture content of the sludge produced.

When the Conference reconvened after lunch, Herman Kratz, Jr., assistant chemist, Bureau of Sewers, Baltimore, Md., read a paper, "Experiments with High Rate Trickling Filters at Baltimore, Maryland," prepared jointly with C. E. Keefer, Associate Engineer, Bureau

of Sewers, Baltimore, Maryland, in which results obtained by high-rate operation of two experimental trickling filters at the Back River Sewage Treatment Works for Baltimore were reported. Effects of varying rate of application, temperature and depth of stone were noted. In a discussion of the paper, L. H. Enslow, Editor, Water Works and Sewerage, regretted the fact that computations made in the Baltimore studies were based on effluents containing the flocculent material sloughing continuously from the filters and called attention once more to the usefulness of filters of this type in handling treatment problems entailing variable loading.

Subsequently, during a business meeting, the following officers were elected for the ensuing year:

President—G. E. Harrington, Washington, D. C.
First Vice President—J. M. Jester, Hyattsville, Md.
Second Vice-President—R. A. Norris, Sykesville, Md.
Secretary-Treasurer—A. W. Blohm, Baltimore, Md.
Executive Committee (Four Year Term)—J. W. Alden, Wilmington, Del.

It was reported that the Association will once more serve as co-sponsor of a short school to be held September 3–5, at the University of Maryland.

Continuing the technical sessions, H. A. Faber, research chemist, The Chlorine Institute, Inc., told those present of progress being made in super-chlorination. J. M. Jester, division engineer, Washington Suburban Sanitary District, related his experiences while attempting to determine the "break-point" of water at the Robert B. Morse filtration plant, Burnt Mills, Md., and also discussed experimental work in differentiating between chlorine and chloramine residuals.

"The Effect of the Washington Sewage Disposal Plant on the Potomac River" was the title of the next paper which was presented by P. D. McNamee, chief chemist, District of Columbia Sewage Treatment Works. This paper presented evidence proving the adequacy of primary treatment given sewage before its discharge into the river. Additional pertinent information was brought out in discussions by R. E. Fuhrman, assistant superintendent, District of Columbia sewage treatment works and R. E. Tarbett, senior sanitary engineer, U. S. Public Health Service.

A banquet, floor show and dance was enjoyed during the evening by nearly 170 members and guests.

The second day of the Conference began with the presentation of a paper "Inexpensive Contrivances Which Have Improved the Operation of a Small Sewage Treatment Works," by C. G. Weber, superintendent, sewage treatment works, Annapolis, Md. Beneficial changes inaugurated by Mr. Weber included changing a point of chlorine application to obtain a reduction in the necessary dose from 20 to 13 p.p.m., a hot water coil heater for his chlorinator, an effective grit removal chamber, an improvised flash mixer for sludge conditioning, use

of settled sewage for elutriating water, installation of gages on the raw sludge pump to indicate which of two valves is inoperative when trouble occurs and an inexpensive sludge weighing device. In his discussion of Mr. Weber's paper, H. R. Hancock, superintendent, sewage treatment works, Dover, Delaware, classified sewage plant operators in an interesting manner. A. L. Genter, consulting engineer, Baltimore, Maryland, complimented Mr. Weber in a discussion of the latter's paper and then considered in detail the effects of elutriation at Annapolis.

L. R. Caplan, Calgon, Inc., read a paper entitled "Keeping Iron In or Out of Solution" in which he noted in detail the effects of adding small amounts of sodium hexametaphosphate to aggressive waters for corrosion inhibition. In a discussion of the paper, L. L. Hedgepeth, director, Technical Service, Pennsylvania Salt Manufacturing Co., reported on a treatment of boiler water with hexametaphosphate. J. G. Patrick, chief chemist, West Virginia Pulp and Paper Company, then discussed the advantages of treating the water supply of a large paper mill with sodium hexametaphosphate.

Leon Small, water engineer, Baltimore, Md., read the last Conference paper, "Construction of the Gunpowder Falls—Montebello Tunnel." Mr. Small mentioned in an interesting manner the final phases of construction of a 7.5 mile tunnel which will bring water to Baltimore for treatment. In his discussion, J. R. McComas, senior assistant sanitary engineer, Maryland State Department of Health, pointed out the fact that the actual net cost of the project to the City would be about five per cent of the total invested.

The Conference closed with a colored movie, "Behind the Water Tap" furnished through the courtesy of the West Virginia Pulp and Paper Company.

An instructive tour of points of interest on the eastern shore of Maryland in the vicinity of Salisbury was arranged for the ladies present and was conducted under the auspices of the Wicomico Women's Club and the Wicomico Historical Society.

C. F. Garland, *Secretary*

Reviews and Abstracts

DISCUSSION OF PROBLEMS OF SEWERAGE AND SEWAGE DISPOSAL IN METROPOLITAN BOSTON

By H. P. Eddy, Jr., and A. L. Fales

Journal, Boston Soc. C. E., 27, 79 (April, 1940)

The pollution of Boston Harbor has been the subject of many investigations and reports by commissions and boards of engineers. In 1938 the State created a Special Commission to investigate the systems of sewerage and sewage disposal in Metropolitan Boston. This commission retained the firms of Greeley and Hansen, and Metcalf and Eddy as consulting engineers to review the previous reports, make new observations, and draw up a report on the pollution in the Mystic River and its major tributaries, and in the Charles River, with methods for correction, and to outline proposed methods of treatment for the three main sewage outlets entering Boston Harbor.

The natural watershed of Boston Harbor has a drainage area of 645 sq. mi., of which 350 sq. mi. are within the area tributary to the sewerage systems of Metropolitan Boston. Thirty-two towns contribute sewage to the three main outlets in the harbor. The principal streams tributary to Boston Harbor are the Neponset, Charles, and Mystic Rivers. Portions of the Charles and the Mystic are used for recreation, particularly boating and bathing. The waters of the harbor are extensively used for shipping, sailing, bathing, and to some extent, for shellfish culture. The principal effects of the discharge of sewage into these waters are the following: sleek areas and sewage fields about the sewer outlets; objects of sewage origin floating on the waters or stranded on the shores; depletion of dissolved oxygen; sewage sludge deposits; and bacterial contamination. The conclusion was reached that the polluted harbor waters are not only objectionable in appearance but are potentially dangerous to the public health to such an extent that preventive and corrective measures should be undertaken by the construction of sewage treatment works. It was considered economically inadvisable to attempt to remedy the objectionable conditions by extension of the outfall sewers.

Sewage from Metropolitan Boston is collected in three systems. The Boston main drainage system, constructed in 1880, serves Boston proper, with a connected population of 415,524. In Dorchester the sewage is pumped after screening through 2¾ in. cage screens. It then flows through two deposit sewers, each 8 ft. wide, 16 ft. deep, and 1,260 ft. long, providing a velocity of about 1 ft. per second at the average rate of flow. The accumulation in the deposit sewers is blown into the harbor once a year and the material deposited there is dredged occasionally. From these sewers the sewage flows to Moon Island where it is stored in four large tanks having a total capacity of 35 million gallons. Originally it was intended to discharge into the harbor only on the second and third hours of the outgoing tide but of late years the quantity of sewage has been so great that it has been necessary to discharge at other stages of the tide. The south metropolitan sewerage system serves the area generally south of the Charles River and west of the main system and has a connected population of 643,690. The sewage flows to Nut Island in Quincy where it passes through grit catchers and cage screens with 1 in. openings and then discharges through three 60 in. cast iron pipe outlets located northwest of Peddock's Island. The north metropolitan sewerage system serves the area north of the Charles River and has a connected population of 696,470. The sewage is pumped twice after passing through cage screens with 2¾ in. openings and discharges into the harbor through multiple outlets near Deer Island Light.

Large parts of the north and south metropolitan districts are served by combined sewers while the remainder of the systems is served by separate sewers that have been misused to a greater or less extent by admission of storm water which they were not intended to carry. These sewers are so designed that the flows in excess of the sewer

capacity are discharged directly into the nearest watercourse, but intercepting sewers collect the dry weather flow for delivery to the outlets in the harbor. Since the capacity of the intercepting sewers is insufficient for much storm water, a large quantity of sewage in time of storm is discharged directly into the streams. Three possible methods of abatement of pollution of the streams were considered: local treatment of the overflow; separation of storm water from the sewage so that existing intercepting sewers will carry sewage only for which they may already have adequate capacity; or construction of storm overflow conduits to intercept a large proportion of the storm overflows. The conclusion was reached that abatement of pollution could best and most economically be accomplished by the construction of storm overflow conduits of sufficient capacity so that no overflows into the streams will occur until the volume of storm water flowing in the sewers has provided sufficiently great dilution of the domestic sewage to prevent objectionable conditions from the overflows. A dilution factor of ten was chosen for most of the waters. These projects have an estimated cost of construction of $14,695,000.

In order to remedy the objectionable conditions existing in Boston Harbor it will be necessary to treat the sewage as follows: (1) to remove the floating solids; (2) to remove grease or oil; (3) to reduce the amount of suspended solids capable of forming sludge deposits; and (4) to prevent excessive bacterial pollution of harbor and shore waters during the recreational season. Three plants will be constructed, one for each of the sewerage systems near the present outlets. The flow sheets will all be similar and will consist of 4 in. racks ahead of pumps, followed by bar screens with ¾ in. openings. The screenings will be burned in incinerators. Mechanically cleaned grit chambers will follow and the grit will be used for fill. The sewage will then pass to aero-chlorinating tanks having a detention of 3 to 4 minutes at average flow. Air at 0.02 cu. ft. per gallon and chlorine at 2 to 3 p.p.m. will be introduced. Sedimentation tanks come next, with a detention of one hour at average flow and 20 min. for storm flows. During the bathing season 15 to 20 p.p.m. of chlorine will be used ahead of the settling tanks to disinfect the sewage. Sludge will first be pumped to storage tanks and then will be discharged to barges which will haul it to sea for ultimate disposal. The plants will be designed for handling the loads from the estimated 1955 population. The following table presents pertinent data on each plant:

	Design Population	Des. Flow M.G.D.	Est. First Cost	Est. Yearly Oper. Cost
Boston Main Drainage	400,000	70	$3,180,000	$240,000
South Metropolitan	900,000	90	3,058,000	249,000
North Metropolitan	750,000	125	3,180,000	240,000

The first cost includes items of $500,000 for a sludge vessel at each plant. The Massachusetts Legislature passed an Act last year authorizing the Metropolitan District Commission to start on work amounting to $10,428,000, subject to the contribution of 45 per cent by the Federal Government. These projects include storm overflow conduits and pumping stations for the abatement of pollution of the Charles River, sewage treatment works for the south metropolitan district, and an extension of the north metropolitan relief sewer.

ROLF ELIASSEN

POLLUTION OF BOSTON HARBOR

BY S. A. GREELEY

Journal, Boston Soc. C. E., **27**, 102 (April, 1940)

In the work of the consulting engineers retained by the special commission investigating the systems of sewerage and sewage disposal in Metropolitan Boston, considerable

study was given to bacterial pollution. As a yardstick, based on experience elsewhere, a single *B-Coli* index of 1,000 per 100 c.c. was accepted as a warning that excessive contamination might be present at times, and that an average index in excess of 3,000 *B-Coli* per 100 c.c. showed that the waters might be dangerous to the public health. A series of bacteriological analyses had been made by the State Department of Public Health in 1929–30, 1935, and 1936. The number of sampling stations were 120, 84, and 162, respectively. These results were plotted on maps showing the average and maximum *B-Coli* indices all over the harbor. Charts showing the effect of winds on the indices were also developed. Similar observations were made on sleek fields.

ROLF ELIASSEN

PROCEEDINGS OF THE TWENTY-FIRST TEXAS WATER WORKS AND SEWAGE SHORT SCHOOL

Sewerage Division, pp. 75–139 (1939)

The Sewerage System Operators' Certification Program Progress and Future Aims. By E. M. J. Berg, pp. 75–77. Author discusses the desirability of certification and states general requirements which should be met by operators to obtain grade A and grade B certificates. The present program is entirely voluntary. There are approximately 2,000 men engaged in sewage plant operation in Texas. At date of writing approximately 86 had been certified.

Certification from the Operator's Standpoint. By Jack M. Jones, pp. 77–78. Author concludes that the voluntary certification program is a distinct advantage to the operator for following reasons (1) gives operator an opportunity to play a recognized and competent part in the maintenance of public health and sanitation, (2) arouses operator's interest in technical side of plant operation and offers chance to familiarize himself with the problems pertaining to sewage treatment, (3) adds responsibility to his job, keeps it free from politics and consequently gives him a feeling of greater economic safety and stability. Net result is greater satisfaction with work and an increasing knowledge and ability to do the work.

Beneficial Effects of Vocational Training of Sewage Treatment Plant Operators. By J. R. Eddy (Discussion by David Smallhorst), pp. 78–82. Author discusses importance of proper training of workers for public service occupations and states that a properly functioning training program should achieve the following results: (1) Better and more efficient operation of present plants. (2) Better understanding by public officials and employees of the problems of sewage disposal. (3) Installation of adequate and more-up-to-date equipment and processes. (4) Development of a pride in his job by the operator and a desire to study his vocation carefully.

Information obtained as a result of questionnaires sent out following special instruction indicated that the chief benefit of such instruction was that it enabled the operators to better understand the elementary principles involved in the operation of their plants. Instruction also encouraged further study and reading and gave the operators an opportunity to discuss their common problems. Questionnaire further indicated that plants were better operated and maintained after the operators received special training.

Author states that a training program should be carried out in three ways; namely, through short schools, through regional schools under the direction of an itinerant instructor, and through local schools under the leadership of some qualified local person.

The discussion gives a summary of how the sewage works training program and other such training schools have helped the Corpus Christi-Nueces County health unit in carrying out its program.

Theory and Practice in the Underground Disposal of Oil Field Brines. By Ludwig Schmidt and C. J. Wilhelm, pp. 82–89. Concerning the disposal of brines the authors state that the return of mineralized water usually referred to as "oil field brines" to

subsurface formations is quite successful in some fields but in other areas this method cannot be recommended. They also say that there is no wholly satisfactory method of brine disposal and that whenever possible oil and gas operators should restrict the underground flow of salt water into their wells.

Methods of brine disposal discussed are: evaporating ponds, impounding reservoirs from which brine may be released during high water, stream-control systems which involve release of brine at a rate that will always insure sufficient dilution, diversion into selected surface streams, and return to subsurface formations. Dissolved solids in brines may vary from 3,000 to 400,000 parts per million. Salts found are mainly the sulfates, chlorides, bicarbonates and carbonates of calcium, magnesium and sodium. Bromides, iodides, strontium and barium are often found. Dissolved gases commonly found are carbon dioxide or hydrogen sulfide or both.

Corrosiveness of brines varies considerably and depends upon the kinds and concentrations of dissolved salts and gases. Magnesium chloride, carbon dioxide, hydrogen sulfide and oxygen increase corrosion rates.

Subsurface disposal formations should be highly permeable and require low brine injection pressure. Both limestone and sandstone formations are used.

The general practice of underground disposal of brines is influenced by the character of the disposal formation, stability of brine as regards precipitation, corrosiveness of brine, volume of brine to be handled; probable life of oil lease and probable income.

Conditioning systems for treatment of brine prior to disposal are classified as: (1) Complete stabilization systems, (2) partial stabilization systems. Complete conditioning systems nominally include aeration for H_2 and CO_2 removal, coagulation, sedimentation, and sand filtration. Partial conditioning commonly includes sedimentation and filtration. (Detailed study given in Bureau of Mines R.I. 3434, "Typical Oil Field Brine Conditioning Systems.") It is advisable that only corrosion resistant materials be used in most gathering, conditioning and disposal systems.

Authors conclude that subsurface disposal of brine is limited to areas where (1) a subsurface formation is available that will take the brine, (2) a more economical method is not available (*e.g.*, disposal by dilution), (3) injection into a subsurface formation will not result in migration of the brine through poorly plugged wells or around casings of oil wells into producing formations or fresh water horizons and, (4) treating, if required, will not be expensive.

Texas Practices in the Disposal of Oil Field Wastes: A Review of Existing Conditions. By H. K. Arnold, pp. 89–91. Pollution may come from drilling fluids, waste oil and salt water. The problem of adequate disposal of these wastes is complex and many influences militate both for and against its satisfactory solution.

Proration, or restricted daily production, has probably been the greatest single influence in producing better operating practices tending to reduce pollution.

Many leading oil companies have assigned the study of salt water disposal to their research staffs in an effort to find methods of utilizing water drive in prolonging the flowing life of oil fields thus increasing oil recovery, decreasing operating expense and minimizing the salt water problem.

Tests conducted and under way in East Texas encourage the hope that a new disposal method with both physical and economic possibilities may have been discovered. (No details given.)

Small Town Sprinkling Filter. By C. E. Collins, pp. 91–93. General.

Sewage Plant Control through Reports and Testing. By J. M. Lloyd, pp. 93–95. Discussion is confined to chemical treatment and covers H_2S control, chlorination, ferric chloride manufacture, coagulation, aeration and laboratory control as practiced at Tyler, Texas. Author's experiences with various treatment combinations are given.

A New Type of Sewage Treatment Plant for Texas—West University Place Plant. By J. C. McVea, pp. 95–96. Local conditions made it necessary (1) to carry out primary treatment in such a way that no objectionable odors could escape and cause nuisance in a residential district to be developed near plant, (2) to provide a high degree of sec-

ondary treatment so the discharge of effluent into a low flow stream which passes through city would not cause odor nuisance.

First condition was met by carrying out the primary and digestion processes in closed tanks, under vacuum whereby all gases could be collected and burned. Secondary treatment was obtained by use of a high-rate trickling filter ("Aero Filter").

The three primary sedimentation tanks have hopper bottoms and each is equipped with a vacuum sludge pump. Pumps discharge to two closed separate sludge digestion tanks. Effluent from primary tanks periodically discharges into a dosing tank from which it periodically discharges through a syphon into a secondary wet well from which it is continuously removed by centrifugal pumps to the filter. Author states that the primary function of the dosing tank is to produce a vacuum for drawing off the gases which are produced in the primary and digestion tanks, and to operate the sludge pumps. (No other details given.)

Filter is circular in plan and stone is 8 ft. deep. Sewage is applied by a rotary distributor which distributes sewage over the bed in a rain-like spray. Filter unloads continuously and secondary sedimentation is accomplished in three tanks, the sludge being returned to primary wet well. Filter equipment includes an automatic valve for recirculating a portion of secondary effluent at periods of low flow. Continuous operation is said to prevent filter flies and freezing during winter operation. Proper ventilation is essential to effieient filter operation. No operating data are given.

Sewage Disposal Plant, Bay City, Texas. By H. J. Wilkins, pp. 96–98. Plant consists of initial sewage lift station, grit chamber, screen, second lift station, settling tanks equipped for mechanical sludge removal, trickling filter, secondary settling tank, and hypochlorination equipment. Design population 6,000. Design flow, 362,000 g.p.d. (50,000 g.p.d. infiltration allowance included). Design flow based on computations made from actual gaugings of present flows. Minimum detention time in primary tanks 1½ hours.

Settled sewage is applied to filter at a constant low rate through a reaction type distributor. Filter is 8 ft. deep and media is graded 1½ in. to 3 in. stone. Effluent from secondary tank is collected in a tee-shaped trough having transverse trough located at a point about 1/3 the length of the tank from the effluent end. Hypochlorination equipment for treatment of effluent is provided. (Any by-passed raw sewage can also be chlorinated.) Secondary sludge is returned to lift station.

Sludge is digested in a 35 ft. diameter tank equipped with a steel floating cover. Five supernatant outlets are provided and supernatant is returned to lift station. Provision was made for sampling the sludge at various levels. At present all sludge gas is burned in a waste gas burner. Digested sludge is dried on open beds. Drainage from beds flows to lift station.

No operating data given.

Plant is equipped with by-pass lines for any unit and city water is available at several points. Entire site was graded 2 ft. above normal level and is planted with St. Augustine grass and shrubs. Hire and purchase method was used in construction. Total cost was approximately $50,000.

Expected Results and Operating Procedure of a Modern Contact Aeration Sewage Disposal Plant for a Small City. By Doak Rainey, pp. 98–102. This is a discussion of the application of the Hays Process to the design of a plant for a city of 2,000. Plant discussed has a design capacity of 150,000 g.p.d. Primary treatment is accomplished by coarse screens and a 45 minute sedimentation period. Sludge is digested in a separate tank. Open drying beds are provided.

Principle of Hays process is the progressive arrangement of the various broad groups of aerobic sewage organisms under conditions most favorable for their growth so that sewage will be acted upon by each group in succession without inhibiting influences of preceding groups.

Application of Hays process begins in two rectangular aeration tanks (8 × 16 ft.) having a 7 ft. water depth. Vertical cross wall divides each tank into two square compartments. Each compartment has a steeply hoppered bottom for sludge collection.

The cross wall acts as a weir over which sewage passes from one compartment to another. Sewage enters the aeration tank at the end of one compartment and is directed downward by a vertical baffle. Sewage flows under this baffle and upward through a square compartment passing over the submerged weir to the second compartment which is equipped with a similar vertical baffle. Second compartment is provided with an effluent launder which removes aerated sewage. The second aeration tank is of similar construction. Both compartments of first stage tank contain vertical sheets of exnaded aluminum spaced at 2 in. intervals. The sheets extend from two inches below water surface almost to the bottom of the vertical tank walls and rest on grills. These sheets distribute upward flow and prevent short circuiting and serve as a contact surface. An air distribution system is suspended below the contact plate supports and consists of parallel ¾ in. aluminum pipes, one foot apart and set on one ft. centers. These pipes are drilled with ⅛ in. and 3/16 in. holes on 6 in. centers.

The second stage tank contains rock graded from 2½ in. to 3½ in. and supported on grills. Air distribution is identical with first tank.

The first stage aerator has a detention time of about one hour and the settled sewage which passes upward between the sheets of aluminum is acted upon by the biological growths which form on the sheets after about one week of operation. In the presence of diffused air biological purification takes place. There is a continuous sloughing of the zoogleal film on the contact plates. Heavier sludge settles into hoppers below plates from which it is pumped to the digester. An intermediate settling tank follows the first stage aeration tank. This settling tank effluent is subjected to further biological purification in the second stage rock filled, aeration tank from which it passes to a final settling basin which is similar to other two tanks except that detention time is only 30 minutes.

Author states that based on five years' pilot plant experience, treatment plant should effect more than 90 per cent B.O.D. reduction and is capable of handling wide variations in sewage strengths. Tests have indicated adaptability to treatment of liquids such as milk wastes.

Plant will occupy about ¾ acre (could be condensed to ⅛ acre), cost $15,000 (exclusive of land), treats 150,000 g.p.d. Power costs including pumping expected to be $25.00/month maximum. Operation and maintenance estimated at 4 man-hours per day. Air requirements 85 to 135 c.f.m. at 3.4 p.s.i.

Advantages claimed for this process over other aeration and oxidation processes are, (1) less than one-half total space for ground and plant size (entire treatment in 4 hours), (2) less than one-half of the energy required for other complete treatment processes due to short aeration period and shallow depths of the tanks, (3) total first cost for construction two-thirds usual cost, (4) high purification effected, (5) simple operation, (6) adaptable to widely varying sewages, (7) shallow tanks facilitate construction where excavation is difficult.

Operating Research Studies. By E. J. M. Berg, pp. 102–103. Studies at the San Antonio plant indicated that at certain periods air in excess of 1,000 cu. ft. per pound of B.O.D. load in primary effluent failed to yield satisfactory treatment with sludge index at 400 (badly bulking). Normally this air to B.O.D. ratio was satisfactory. Author believes that bulking can be attributed in part to digester supernatant which is received by primary clarifiers and that 1,000 lb. of digester supernatant B.O.D. are far greater in effect than 1,000 pounds of normal sewage B.O.D. "There is a lasting poisoning effect on activated sludge by the digester supernatant liquor. Activated sludge in good condition can handle considerable supernatant return but if sludge is initially near bulking due to continual slight underaeration it is sensitive to even small amounts of digester supernatant liquor."

Studies were made to determine some definite mathematical relationships between amount of activated sludge suspended solids and suspended solids in primary effluent. Ratio of p.p.m. suspended solids in return activated sludge to p.p.m. suspended solids in primary effluent, each weighted according to their respective daily flow is called R, a dimensionless number. Sample calculation: Sewage flow 18 m.g.d.; primary effluent suspended solids, 120 p.p.m.; return sludge 6 m.g.d. with 4,500 p.p.m. suspended solids.

$$R = \frac{6 \times 8.33 \times 4500}{18 \times 8.33 \times 120} = 12.5$$ or 12.5 lbs. of return sludge solids for each pound of solids that the incoming sewage brings into the aeration tanks. Study of records at San Antonio and experimental work indicated best plant performance with R between 8 and 10. Higher values of R gave poorer results. Author suggests tentative value of 10 but warns that conclusive evidence has not been established.

Suggested Items to Consider in Interstate Agreements. By V. M. Ehlers, pp. 103–105. The author suggests that the cardinal principle that might be adopted is the recognition of the power of a stream or waterway to effect a certain degree of purification through natural reactions. In view of this it is suggested that limiting conditions be established for interstate streams. Standards proposed for discussion are (1) "No industrial nor domestic wastes, nor oil field brines, shall be allowed to enter an interstate stream such that the receiving water would have at mean low water flows (based on yearly average data) a B.O.D. increase greater than 25 per cent, a dissolved oxygen reduction greater than 20 per cent, and a chloride increase greater than 50 per cent . . ." (test stations to be located 500 feet above and below source of pollution).

(2) "In the case of pollution that originates some distance back from the interstate boundaries, then the standards for such interstate streams as have been adversely affected by pollution should have the following values as a minimum at the point where they enter the interstate boundary area: B.O.D. not greater than 20 p.p.m.; chloride content as Cl^- not greater than 300 p.p.m.; dissolved oxygen content not less than 4.0 p.p.m. These tests should be made at the point at which the waste enters the interstate area and any lowering of these standards would indicate that the stream had been materially damaged in the originating state."

Controlling Infiltration in Sewer Lines. By H. R. F. Holland. (Discussion by W. F. Hicks), pp. 106–111. This discussion mainly applies to pipe sewers as large monolithic or built-in-place sewers present a different problem.

Present trend in jointing is toward use of special jointing compounds whereas in past they were used only for wet ground. Wide use of such compounds has been retarded due to cost and also to fact that careful workmanship yields a satisfactory joint by the use of mortar. Author defines ideal jointing material as one rigid enough to hold pipe in place and form a close bond with pipe yet at same time having enough flexibility to prevent opening of the joint with slight settlement.

Specifications at Austin, Texas, called for infiltration not greater than 20,000 gallons per mile of sewer per day, no distinction being made in the size of sewers which ranged from 6 in. to 30 in. diameter. Actual *outward* leakage measurements were made by filling pipe with water (5 ft. head maximum) and measuring loss in a given time. From this exfiltration in g.p.d. per mile was calculated. Typical results for various diameters in g.p.d. per mile were: 15 in., 3,870; 15 in., 19,800; 30 in., 12,000; 8 in., 4,750; 8 in., 14,900; 6 in., 2,200; 6 in., 9,500. Tests were made during construction. Excessive leakage in most cases was due to broken pipes which resulted from careless backfilling methods. In some instances it was due to failure of contractor to cement caps on wyes and tees left in the line. (Description of tests were published in *Eng. News-Record* and *Southwest Water Works Journal* in 1933.) Author's experience, however, leads to conclusion that greatest cause of leakage or infiltration is carelessness in making joints.

Data on infiltration from several sources are quoted and discussed. The effect of, and conditions favoring, soil movement are briefly considered.

In conclusion author suggests that the following be observed: (1) Proper design and careful supervision of construction, (2) Careful consideration of proper joint material for local conditions and proper joint construction, (3) Rigid control of the construction of house connections, and (4) Elimination of unauthorized openings into the sewers and house lines.

In the discussion the greatest source of infiltration, based on experience of author, is from service lines and faulty plumbing. Bituminous joints for vitrified clay pipes are recommended. Cleaning, and painting bell and spigot with asphalt paint are essential in making this type of joint. Five and one-half miles of sewer line constructed with

this type of joint had maximum infiltration rate of 12,500 g.p.d. Pipe sizes were 24 in., 15 in., 12 in., 10 in. and 8 in., all vitrified clay. Rainfall was 50 per cent above normal during test and author believes large percentage of water entered through manholes. Joints on 200 ft. of half exposed 24 in. pipe were undamaged by summer temperature up to 107° F. Joints were made with hard asphalt (10 penetration) mixed with stone dust pound for pound.

Sources of excessive storm water flows are located by a systematic check of flow through manholes during storms.

The Operation of Sewage Pumps and Construction of Pumping Stations. By Wm. E. White, pp. 111–115. Station should contain not less than two pumps and where practical largest unit should be capable of handling the average daily maximum flow. This arrangement is economical and provides a stand-by unit for emergencies. If only one pump is used at an automatically controlled station the capacity of the pump and the dimensions of receiving well should be such as to allow rest periods during average daily maximum flow of 15 to 20 minutes.

The permanent features of a pumping station should be so designed that additional capacity can be easily provided.

Author does not recommend the open type impeller pump and city of Houston, Texas, without exception, specifies closed impellers. Additional cost of this type is well repaid by the satisfactory service.

Specific speed $= N_s = \dfrac{\text{R.P.M.}}{\text{G.P.M.} \times H^{3/4}}$ is another important pump feature and represents a characteristic of impellers of similar design. Well-known manufacturer states that N_s should be between 1,300 and 2,000, for non-clog sewage pumps. Low speeds require large diameters and higher initial investment but minimize wear and efficiency loss and are, therefore, desirable.

Another important pump characteristic is the maximum sphere which will pass through the pumps. Houston pumps are required to pass a 3 in. sphere.

A common difficulty at pump stations is failure to design gravity line leading from the station for the ultimate capacity of the station. The deep incoming gravity line may be surcharged but the relatively shallow gravity line leading from station cannot be surcharged. Sewer leading from station should be designed on basis of pumping station capacity rather than incoming sewer capacity.

Operating summary: " (1) Continued leakage through packing gland permits a continuous supply of grit to wear away the shaft sleeve. (2) In a sleeve bearing pump, loose worn bearings may permit chattering at the impeller and serious wear of impeller or impeller wearing rings." . . . (3) Suction line pressure should not be allowed to fall a large amount below atmospheric. " (4) Use a swing check valve with outside stem and lever and adjust the weight so the valve will close as soon as the stream comes to rest. (5) Attention at least once daily is necessary at all automatic stations."

In connection with design: " (1) Provide adequate ventilation in pump. . . . (2) Avoid priming equipment so far as possible. (3) Where increased capacity in a pump is anticipated for the future if motor and casing of the pump are selected so that larger impellers and wearing rings only are needed to provide that increased capacity, material economies may be realized. . . . (4) Beautification of the pumping plant in any location should be given special attention. . . ."

Sewage Irrigation as a Method of Disposal. By R. L. Peurifoy, pp. 115–121. Certain constituents in sewage, as nitrogen, phosphate, potash, calcium and magnesium, are beneficial to soil. Other compounds are objectionable, as chlorides, sulfates, grease, etc. Because of possibility of excessive quantities of undesirable substances it is recommended that samples of the sewage be analyzed before it is used on land. In interpreting the analysis consideration must be given to type of crop to be grown.

The amounts of water required for each pound of various types of crops are computed and tabulated. These vary from 905 lb. of water per pound of flax down to 310 lb. of water per pound of millet.

It is assumed that every person using a sewerage system contributes 8 lb. of nitrogen, 2 lb. of phosphorous and 3 lb. of potassium each year in addition to calcium and magnesium. Four tons of alfalfa per acre per year require 43 lb. of phosphoric acid, 150 lb. of potash and 175 lb. of nitrogen. In order to supply these foods from sewage the following number of persons must supply sewage to each acre: nitrogen, 22; potash, 42; phosphate, 10. A city of 1,000 would supply the nitrogen demand of 45 acres, the potash demand of 23 acres and the phosphate demand of 100 acres based on four tons of alfalfa per acre per year.

Results of irrigation with sewage are tabulated for Kingsville, Texas, and results of a study made at Gainesville, Florida, are quoted. The net income per acre at Kingsville was $57.13. Crops grown were Rhodes Grass and Hegari.

Replies to questionnaires sent out to determine results obtained elsewhere indicated that where favorable results were obtained a qualified and interested operator was in charge, while in those instances where the results were unfavorable the operation was unsatisfactory.

Methods of applying the sewage to the land include broad irrigation, corregation, terraces, rows and wild release with no control. In nearly every case sewage is delivered to field in open ditches. Sloping land is desirable. When land is flat it is necessary to irrigate smaller areas from the flow otherwise there is danger of waterlogging.

Sandy loam is generally considered desirable for irrigation although a reasonably tight surface soil has advantages under some conditions. Subsoil conditions are important.

An earthen storage reservoir sufficiently large to hold the entire sewage flow for at least three months should be built in connection with the irrigation project in order to provide storage when irrigation is not desirable. This storage period is stated to be sufficient to render the sewage safe for discharge into creeks or elsewhere if necessary. Lake must supply sufficient oxygen to oxidize incoming sewage if odors are to be prevented.

Lake at Kingsville (population 8,000, daily sewage flow 400,000 gallons) has surface area of 12 acres and a capacity of 90 acre feet. Author states that a larger area would be desirable but that existing lake has never given trouble of any sort. Lake permits 90 day storage. There is considerable loss through seepage and evaporation. Minnows have lived in the lake since shortly after filling and there have been no mosquitoes.

Conclusions: Success or failure in sewage irrigation depends on operation. Sewage irrigation can be made practical and profitable, through increase in crop yield and land improvement. Sewage disposal by irrigation is safe, effective and economical (24¢/person/year for labor and energy to pump Kingsville sewage). Continued sewage irrigation in outcropping artesian water formations will increase water available in formation. Artesian water drawn from a formation fed by sewage is safe provided the aquifer is sand instead of fissurized limestone. Municipalities in Texas can well afford to seriously consider irrigation as a possible method of disposal.

Sewage Irrigation as a Method of Disposal. By Riley B. Harrell, pp. 121–123. This paper describes sewage irrigation as practiced by the city of Munday, Texas. Cotton proved to be the most satisfactory crop and the author recommends the use of row crops above others since plowing for weed control is essential. Treatment plant effluent is used for irrigation and flow averages about 55,000 gallons daily. Twenty-four acres of land are irrigated and in 1934 (a very dry year) this land produced 23 bales of cotton. Land not irrigated produced less than 1/3 bale per acre and cotton was of poorer quality. Dried sludge is used as fertilizer. Irrigation has solved the problem of effluent disposal which was serious since there were no waterways that the effluent could be pumped into without heavy expenditures for equipment and operations.

Grapefruit Canning Plant Wastes. By H. C. Ratliff. (Discussion by Joe B. Winston), pp. 123–128. Problem of disposal of wastes from grapefruit juice canning plants is encountered in the Rio Grande Valley of Texas and also in Florida and California.

Average canning plant waste has B.O.D. of from 400 to 4,000 p.p.m. and dehydration plant waste or press juice varies from 8,000 to 80,000 p.p.m. Total acidity may be 2,000 p.p.m. or more.

To study waste treatment a pilot plant was constructed at a grapefruit canning plant. Pilot plant had facilities for chemical coagulation and filtration. Filtration of raw unscreened waste through a pea gravel filter was unsatisfactory as was filtration through three-inch gravel. Chemical treatment with lime and alum was also studied and results have served as basis for further study.

Stronger type and larger volume of waste obtained from dehydration plants includes oils and sugars pressed from grapefruit peel prior to the dehydration process. This waste has about the consistency of No. 10 motor oil. Considerable dilution is necessary in connection with treatment. Full scale plant was built to study treatment of this waste.

Design flow, 0.4 M.G.D. which included effluents from five juice canning plants, one dehydration plant, and the final effluent from the city's domestic sewage treatment plant. Treated sewage served as a diluent. Wastes and treated sewage were dosed with lime, alum and activated carbon, then pumped to two 200 ft. × 6 ft. × 15 ft. settling basins (135,000 gallons each), 7 to 13 hours' retention. Settling tank effluent was passed over a trough-type aerator 1 ft. wide, 1 ft. deep and 48 ft. long. Aeration was accomplished by flow passing over and under a series of baffles set across the trough at 6 in. centers. Chloride of lime was added as effluent discharged into ditch where some dilution was obtained from seep water and occasionally from sewage plant effluent. Approximately 70 per cent reduction in B.O.D. obtained. Studies made using six experimental filters having sand, sand and gravel, pea gravel, medium gravel, large rock and a gravel combination for media indicated a further reduction of from 30 to 45 per cent of the remaining oxygen demand. Florida investigators reduced this demand 70 per cent by the use of intermittently dosed rock filter.

Major cities in Hidalga County in cooperation with county and state health departments, passed a standard ordinance requiring all wastes having B.O.D. greater than 250 p.p.m. to be treated prior to disposal in city sewer system. Pre-treatment units were constructed in nearly every canning plant in county. Units included screening through 40 mesh, rotary mechanical screen, chemical coagulation by batch treatment with alum and lime and dilution of effluent with wash and cooling water. Settling tanks vary in capacity from 500 to 1,500 gallons. Tanks are used in pairs alternating between settling and filling; chemicals added by hand and agitation is accomplished by hand or steam. Effluent relative stability varies from 50 to 99 per cent, B.O.D. reduction from 50 to 89 per cent.

An experiment on disposing of dehydration plant press juice by forcing it into an underground strata was tried. This failed since wastes fermented and returned to surface when pressure was removed.

U. S. Department of Agriculture chemists and Texas State Health Department engineers are cooperating on further study of the problem.

The discussion emphasizes the desirability of minimizing volume and strength of wastes by careful plant operation and maintenance of equipment.

Desirability of passing ordinance (previously noted) is questioned in view of fact that highest percentage B.O.D. removal obtained will not produce effluent which meets ordinance if raw waste B.O.D. is greater than about 2,500 p.p.m. Author notes a controversial question as to whether it is best to pass ordinance first and then search for a means to comply or to gain knowledge of treatment methods first and then set up necessary enforcement machinery.

Average juice plant processes 50 to 100 tons of fruit per day and solid wastes, as discarded fruit, peel, rag and pulp offer a serious disposal problem, in addition to liquid wastes. Dehydration of peel for stock feed and use as fertilizer and stock feed raw or in trench silos offers possible solution.

Some Meat Packing Plant Installations for the Treatment of Wastes. By G. L. Childress, pp. 129–133. Basic requirements in packing house waste *abatement* are: (*a*) screening, (*b*) skimming, (*c*) evaporating and drying.

Character of waste and method of treatment depends upon size of packing plant and care with which plant is conducted.

Biological treatment methods have not been favored because of high initial plant cost and because of odor nuisance. Packing house waste solids are largely protein and if treated while fresh by chemical coagulants, 90 per cent will be precipitated.

Treatment plant built by Hormel Company, Austin, Minnesota, after experimental work is described as follows:

Capacity 1.5 m.g.d. Cost $70,000. Primary treatment for grease and solids removal is provided by basin consisting of five bays 40 ft. long and 7 ft. wide. Water depth is maintained at only 6 ft. although tanks are 15 ft. deep since experience has indicated that greater water depths causes circulation with impaired sedimentation. One of five bays serves as sludge reservoir. Grease is skimmed and rendered as inedible grease. Value of grease recovery very low. Detention time in primary tank is about 30 minutes. Next stage involves chlorination in two 15 ft. by 15 ft. by 15 ft. tanks equipped with agitators. After 10–15 minutes mixing, sewage is pumped to a 70 ft. by 70 ft. secondary mechanical clarifier with 8.5 ft. water depth. Proteins in waste precipitate out in 45 minutes. Scum is collected by a mechanical skimmer and returned to mixing tanks. Detention periods are kept short since if protein decomposition starts in primary tank, the amount of protein precipitated by the chlorine is reduced. (Ferric chloride as a precipitant is considered unsatisfactory for protein in all wastes and caused sludge to become rapidly septic. Importance of dealing with wastes while fresh is emphasized.) Daily flow averages 0.9 m.g. with about 100 p.p.m. organic nitrogen. Reductions: Suspended solids, 90 per cent; organic N, 70–75 per cent; B.O.D., 75 per cent. Daily costs: chemicals, $50.00; labor, power and fixed charges, $50.00. Cost of sludge disposal not available and no satisfactory method has been found.

Plant of Kerber Packing Company at South Elgin, Illinois, is described and in principle is similar except that ferric chloride is used instead of chlorine. Plant has sludge storage tank and drying beds, having total area of 1,680 sq. ft. Sludge dries in two to three weeks but might require five weeks under some climatic conditions. Wastes from hog kill first pass to a catch basin where fat is skimmed off by hand. Mixing basin at this plant has a detention time of 21.4 minutes at 250 g.p.m. Plant cost, $20,000.

Tovera Packing Plant at Phoenix, Arizona, uses ferric chloride and all wastes, including paunch manure, are treated in the plant. Solids sometimes reach 12,000 p.p.m. Plant consists of a bar screen (one in. openings), flash mixing and flocculator equipment (flocculation period, 30 min.), and a sedimentation tank having a detention time of 1.5 hours. Effluent B.O.D. averages 200 p.p.m. and is used for irrigation. Plant also has two stage digestion equipment. Sludge gas yield 30,000 cu. ft. per 24 hours. B.T.U. value, 700 per cu. ft. Gas is used for company steam boilers. Sludge dries on bed in from 20–30 days in summer and 30–50 days in winter. Plant cost $40,000.

Author concludes that feasibility of treatment of wastes will depend, in the future, on a solution of the sludge problem and ability of owners to make the installations and maintain the cost of operation.

What One Texas Brewery has Done with Regard to its Treatment Problems. By L. A. Godbold and Louis Fahr, pp. 133. This paper gives average data on the operation of a brewery waste treatment plant which was previously described in the *Sewage Works Journal,* **11**, 2, 295–307 (1939).

Textile Mill Wastes. By Thos. E. Craig. (Discussion: Dudley Perkins), pp. 134–136. Author briefly discusses broad aspects of industrial waste treatment from a sociological and economic standpoint and points out that the principal available material relating to textile wastes has been collected by the Textile Foundation in cooperation with the University of North Carolina in a report entitled "Textile Waste Treatment and Recovery." Author concludes that the great need is governmental support of the agencies now at work on the general solution and further that left to private industry and engineers even tolerable solutions will be slow in evolving due to the time and expense and technical knowledge required.

The discussion points out unsatisfactory nature of chemical treatment of textile wastes, especially sulfur dyes. Method is unsatisfactory because of odor and cost which ranges from 10 to 20 cents per thousand gallons. Rights of riparian owners and uneconomical use of streams are also discussed.

In conclusion author states that textile wastes have adverse effect on ordinary biological sewage treatment plants due to presence of fiber, grease and dye. Greatest damage

is considered to result from the irregular discharge and irregular character of wastes. A biological process may be adjusted to certain industrial wastes provided that the properties of the waste are constant.

Operating Results Secured from Typical Texas Sewage Treatment Plants, Showing Treatment and Efficiency Secured from Various Units. By G. R. Herzik, Jr., pp. 136–139. Data presented are results of studies by the State Health Department in East Texas. Five different efficiency determinations based on five types of samples were made. Samples were: (1) simple composite, (2) weighted composite, (3) single sample taken at maximum flow, (4) single sample taken at minimum flow, (5) single sample at normal flow. Preference given method (2).

Flowing through periods were checked at one plant with fluorescein dye with following results.

Unit	Theoretical Detention Period, Minutes	Flowing Through Period, Minutes
Settling basin	58	30
Aerator	50	23
Settling tank	30	10
Dosing tank and filter	16.5	16.5
Final settling tank	30	10

Author does not recommend use of fluorescein dye in view of expense and because color is often destroyed or materially reduced in passing through the unit.

Remainder of paper is devoted to presentation of data relating to percentage removal of suspended solids, B.O.D. and oxygen consumed at several plants. Data are given for both primary and secondary treatment units.

PAUL D. HANEY

RECTANGULAR TANKS—EFFICIENCY AND ADAPTATION TO DESLUDGING MECHANISM

BY H. D. THATCHER

The Surveyor, 97, 493–4 (June 7, 1940)

The author devotes the initial portion of the paper to a general discussion of settling tank efficiency—its importance and the improvement therein that may be wrought by suitable inlet design and by prompt removal of the settled sludge.

The latter portion of the article deals in particular with the sludge removal mechanism which consists of a scraper blade suspended from a traveling bridge spanning the tank. Some of the advantages cited for this type of equipment are: (1) It can be lifted entirely out of the sewage when not in use, (2) once the scraper blade has passed any particular point during desludging, there is no further risk of disturbance to sedimentation, (3) speed of desludging may be set to accommodate light sludges, and withal, to complete the operation in a short time due to the fact that but a single sweep of the mechanism is required, (4) painting and renewals may be accomplished without putting the tank out of service, (5) scum removal may be accomplished at either or both ends of the tank, (6) low power consumption, and (7) one machine may be used to desludge a number of tanks by providing the proper transfer arrangements.

V. G. MACKENZIE

SEWAGE DISPOSAL AT ROCHDALE

The Surveyor, **98**, 19–20 (July 12, 1940)

The dry weather flow of sewage from Rochdale amounts to 3.0 m.g.d. The principal trade wastes are gas liquor and wool scouring refuse. Two main outfalls convey the sewage to the treatment plant, which at present is undergoing reconstruction. The existing treatment plant provides for coarse screening, detritus removal, preliminary sedimentation with separate sludge digestion, oxidation by trickling filters, and final settling. Storm water settling tanks are located on each of the main outfall sewers below the point of diversion to the treatment works.

The new extension provides for treatment of 3.2 m.g.d. dry weather flow, of which half will be treated by trickling filters and half by activated sludge. Complete treatment will be furnished to flows up to 3 times the dry weather average. For excess flows it is planned to increase the storm water settling tanks to a volumetric capacity equal to 0.3 the average daily dry weather flow, but existing war conditions have necessitated the postponement of part of this construction.

In the enlarged plant, sewage will first enter a three compartment detritus tank, arranged to provide a constant velocity of 1 ft. per sec. by means of automatic sluice gates. Following detritus removal, the sewage will pass through mechanically cleaned bar screens with one-inch clear openings. Screenings will be disintegrated and returned to the sewage.

Preliminary sedimentation will be provided in a mechanical equipped clarifier, with 1.17 hr. detention period. Following sedimentation, 50 per cent of the sewage will flow to the existing trickling filters, of which there are thirteen, 72 ft. diameter and seven, 99 ft. diameter units, all of 9 ft. depth. Secondary sedimentation will be furnished by six existing rectangular plain tanks, providing 10.5 hr. detention.

The activated sludge plant will consist of six units, each having two aeration tanks and four final settling tanks. One unit may be used for sludge reaeration. Detention of 16 hr. for aeration and 6 hr. for settling is provided. Aeration is effected by the Kessener brush system in which a rotating longitudinal brush, located on one side of the tank at the surface, aerates the liquor and imparts a spiral flow to the tank contents.

The existing digesters will be utilized for sludge digestion. Gas will be collected from the heated primary digester which has a capacity of 68,400 cu. ft. Two secondary digesters, of 112,000 cu. ft. total capacity, will be unheated.

For air raid precautions, storm overflows have been fixed in the main sewers and at the treatment plant, and these may be used to divert the sewage to the river if necessitated by damage.

V. G. MacKenzie

SEWERAGE AND SEWAGE DISPOSAL IN SINGAPORE

The Surveyor, **98**, 33 (July 19, 1940)

At present, less than one-fifth of the total municipal area of Singapore is sewered. With the completion of the present sewerage extension scheme, which includes two additional disposal works, the area served will increase to about one-half the total area and will include most of the built-up portions.

The existing Alexandra-road plant treated an average sewage flow of 6.169 m.g.d. in 1939 and, in addition, 15,394 pails of nightsoil daily which were flushed directly to the digesters. Sewage treatment consists of detritus removal, preliminary sedimentation, oxidation by trickling filters, and secondary sedimentation.

Preliminary sedimentation is furnished by six upward flow tanks and a mechanically-equipped clarifier. A reduction of 56.5 per cent of the suspended matter was effected by these units in 1939, the effluent averaging approximately 150 p.p.m. The oxidation and final settling units produced a plant effluent of "good standard." Loading on the trickling filters averaged 4 gal. per cu. yd. per hour, excluding long rest periods which were found to be unnecessary.

An experimental bio-flocculation unit was operated during 1939. Detention averaged two hours on the day flow. It was found that an exceptionally good trickling filter effluent could be obtained with a filter loading of 195 gal. of bio-flocculation effluent per cu. yd. per day, whereas the maximum rate at which sedimentation tank effluent could be filtered continuously was 150 gal. per cu. yd. per day.

Primary sedimentation sludge and diluted nightsoil underwent two-stage digestion, the mixed raw material being seeded with approximately one-third its volume of primary digested sludge. By digestion, the ratio of organic to inorganic matter in the sludge was reduced from 4.3:1 to 2.4:1. Before drying on the sludge beds, all digested sludge was heated to 140° F. for at least 20 min. to kill hookworm larvae. Gas collected from the primary digesters was used for lighting, heating the sludge to kill hookworm, and in a small plant drying sludge for fertilizer. A portion of the plant sludges were disposed of as fertilizer and the remainder buried.

V. G. MacKenzie

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CONVENTION NEWS

FIRST ANNUAL CONVENTION FEDERATION OF SEWAGE WORKS ASSOCIATIONS

Sherman Hotel, Chicago Illinois

PROGRAM

October 3rd, 1940

9:30 A.M.	**Registration**	
10:30	**Address of Welcome**	William H. Trinkaus
10:45	**Response**	C. A. Emerson
11:00	"New Developments in Activated Sludge Plant Operation"	Gail P. Edwards
11:30	Discussion	Don E. Bloodgood
11:50	"The Rôle of Sphaerotilus Natans in Activated Sludge Bulking"	C. C. Ruchhoft and John F. Kachmar, Jr.
12:20 P.M.	Discussion	H. Heukelekian
12:30	**Non-programmed Luncheon**	
2:00	The Rôle of the Trickling Filter in Sewage Treatment"	Max Levine
2:30	Discussion	Linn H. Enslow
2:50	"New Operating Results in the Chemical Treatment of Sewage"	Willem Rudolfs
3:20	Discussion	E. Hurwitz
3:40	"Sewage Flows and Composition Affecting Treatment"	A. M. Rawn
4:10	Discussion	Robert A. Allton
4:30	"Recent Trade Waste Disposal Methods"	E. F. Eldridge
5:00	Discussion	L. F. Warrick
8:30	**Smoker**	

October 4th, 1940

9:00 A.M.	"Progress in Conditioning Sludge for Dewatering"	Frank Woodbury Jones
9:30	Discussion	Harry A. Faber
9:40	Discussion	C. E. Keefer
10:00	"Mechanical Equipment in Sewage Treatment"	Lloyd M. Johnson
10:30	Discussion	Charles Gilman Hyde
10:50	"Sludge Gas Utilization"	Ralph E. Fuhrman
11:20	Discussion	W. B. Walraven
11:40	"Dual Disposal—Where Does it Stand?"	Edward J. Cleary
12:10 P.M.	Discussion	L. R. Howson

12:30	**Non-programmed Luncheon**	
2:00	"Instruction in Sewage Treatment"	Gordon M. Fair
2:30	Discussion	H. E. Babbitt
2:50	"Licensing Sewage Plant Operators"	Charles C. Agar
3:20	Discussion	C. W. Klassen
3:40	**Business Meeting**, Central States Sewage Works Association. Presiding	B. A. Poole
7:30	**Banquet**	

October 5th, 1940

8:30 A.M.	**Operators' Breakfast**—Leaders	Kerwin L. Mick and M. W. Tatlock
10:00	**Business Meeting.** Federation of Sewage Works Associations. Presiding	C. A. Emerson
12:15 P.M.	**Luncheon**—Address	Abel Wolman
	"An Inquiry into Standards Proposed for Stream Cleanliness"	
2:00	**Inspection,** Chicago Southwest Sewage Treatment Plant	

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Double room, with bath	4.00
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Suites	10.00

Advance reservation is recommended, as the number of rooms at these prices is limited.